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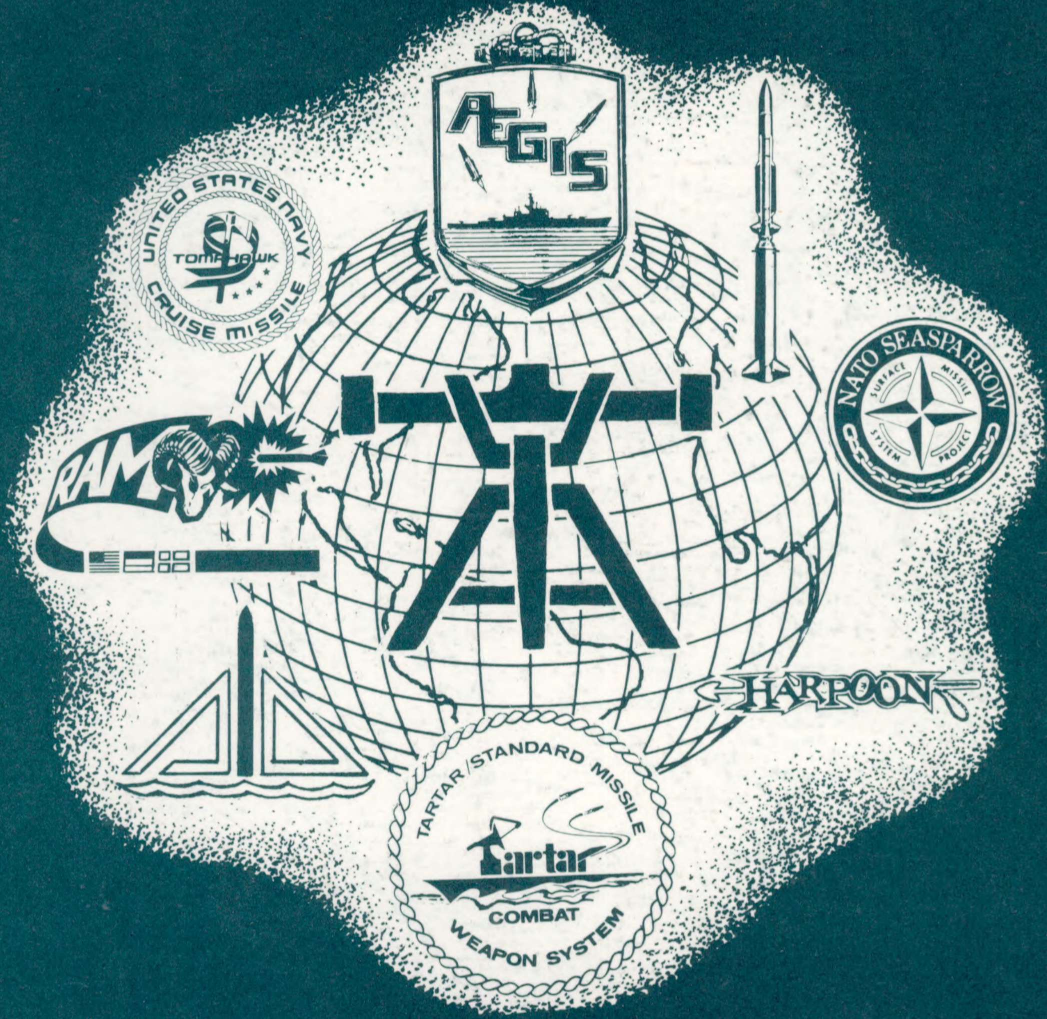

FIRE CONTROL TECHNICIAN M 3

NAVAL EDUCATION AND TRAINING COMMAND
RATE TRAINING MANUAL AND NONRESIDENT CAREER COURSE

NAVEDTRA 10224

Although the words "he", "him", and "his", are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *Fire Control Technician (M) 3*, NAVEDTRA 10224.

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Naval Education And Training Program Development Center

FIRE CONTROL TECHNICIAN M 3

NAVEDTRA 10224

DEPARTMENT OF THE NAVY ★ CHIEF OF NAVAL EDUC AND TNG ★

1981 Edition Prepared by
FTCS Gilbert J. Cote'

PREFACE

This Rate Training Manual and Nonresident Career Course (RTM/NRCC), *Fire Control Technician (M) 3*, NAVEDTRA 10224, is intended to provide enlisted personnel with background information necessary for advancement to the rate of Fire Control Technician (M) Third Class. This includes information on missiles, weapon control systems, missile system testing and safety, fire control radars, support systems, administration, and general maintenance.

Designed for individual study vice formal classroom instruction, the RTM provides subject matter that relates directly to the Occupational Standards of the Fire Control Technician (M) 3 rate. The NRCC provides the usual way of satisfying the requirements for completing the RTM. It consists of a set of assignments which include learning objectives and supporting questions designed to help students complete the RTM. You may find it beneficial to browse the entire training package and to read the front matter to the NRCC before you begin serious study.

This training manual and nonresident career course was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Special credit is given to the following commands for their reviews during the preparation of the manual: Naval Sea Systems Command, Washington, D.C.; Naval Ship Weapon System Engineering Station, Port Hueneme, California; AEGIS Combat Systems Engineering Development Site, Moorestown, New Jersey; Naval Guided Missiles School, Dam Neck, Virginia; Combat Systems Technical Schools Command, Mare Island, California; and Service Schools Command, Great Lakes, Illinois.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

THE FIRE CONTROL TECHNICIAN (MISSILE)

This rate training manual has been prepared for men and women of the Navy, and of the Naval Reserve who are studying for advancement to the rate of Fire Control Technician (Missile) 3. One of a series of rate training manuals, this manual is designed to give you background information necessary for the proper performance of duty at the third class level. The manual is based on the professional qualifications for FTM3, as listed in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068 (current edition).

The requirements for advancement in rating are discussed in *Military Requirements for Petty Officer 3 & 2*, NAVEDTRA 10056 series. When you are studying for advancement, always make sure you have the latest edition of NAVEDTRA 10056. Also, you should check with the educational services office of your command for possible changes to the requirements listed in the manual.

The purpose of this chapter is to introduce you to the rating for which you have been selected. The term "fire control" means the directing of various weapons so that they will hit a desired target. As you learn about fire control, you will realize that the Navy is only as strong as its fire power and in order for its fire power to be effective, it must be accurately controlled. That is where you, as a fire control technician, will play a vital part in making your ship an effective weapon against ships, planes, and shore installations. It will be your job to operate and maintain the many complex devices used in your ship's various fire control systems.

THE FT RATING

The fire control technician rating is a general rating at the E-8 and E-9 level. At E-7 and below, the rate is divided into three service ratings as follows:

FTM (Surface Missile Fire Control)

FTG (Gun and Underwater Fire Control)

FTB (Ballistic Missile Fire Control)

Specialty groups within these ratings have been assigned Navy Enlisted Classification (NEC) codes. The NEC code numbers reflect special knowledge and skills of personnel. An NEC code is normally assigned to an individual after that person has satisfactorily completed the "C" school course on a related fire control system or equipment.

Normally, you will be assigned duty according to your NEC code. As an FTM3, your assigned billet will probably call for an equipment specialist. This, however, does not relieve you of the need to acquire overall knowledge of missile fire control. This will become evident on your first advancement in rate examination.

DUTIES AND RESPONSIBILITIES

Missile fire control technicians operate, test, maintain, repair, and align shipboard missile fire control systems, weapon direction systems, three-coordinate air search radars, related support equipment, and, in certain cases, missiles. To fulfill these duties, you as a missile fire control technician must be able to:

Perform all periodic cleaning, lubricating, and testing required on the equipment in your charge.

Use all the tools and instruments, mechanical and electrical, called for.

Read and interpret mechanical drawings, electrical schematics, and wiring diagrams.

Locate problems (troubleshoot), and make needed repairs.

As an FTM3, you must also be able to requisition spare parts and supplies. You must know how to prepare work requests and to document completed maintenance. Also, you must maintain fire control records (logs), according to the established format.

Do not let this list of duties awe you. You will not have them piled on your shoulders all at once. Other FTs aboard, who have been doing this job for some time, will help you get started on the right foot.

As you increase your skill and knowledge, your range of duties will also increase. Third class is only a step up the ladder of success. There is no limit to how far you can go in the Navy. Your division officer or weapons officer may have started their careers as FT strikers. Remember, the path to advancement is open; the rest is up to you.

HISTORY OF FIRE CONTROL

Warships in early and medieval times engaged in war on the seas by ramming, or by grappling the vessel and boarding it for hand-to-hand combat. Guns were not used on ships on a large scale until the fifteenth century, when a Spanish fleet opened fire with cannon at point-blank range on the Turkish fleet, which was quickly defeated.

Less than 200 years ago, naval guns were still fired at point-blank range. Gunnery was still an art, not a science, and fire control was largely a matter of skillful seamanship in steering the ship into position to enable the gunners to hit the target. The range and destructive power of guns continued to increase over the years, from an average effective range of 100 yards in the mid-1800's to more than 40,000 yards in the mid-1900's. These improvements in gun ranges could make guns effective only if the guns were accurately aimed. Methods of fire control in the modern sense were not developed until the nineteenth and twentieth centuries.

GUN SIGHTS

The first concern of a fire control system is to provide an effective way of aiming. This is the function of the gun sights. Prior to 1800, there was no need for elaborate gun sighting systems, because the guns themselves were inaccurate except at close range. Guns were simply pointed at the target by eye.

Gun sights introduced early in the nineteenth century consisted of fixed front and rear sights mounted so that the line of sight across their tips was parallel to the bore of the gun. Toward the end of the nineteenth century, a sight telescope (fig. 1-1) was developed by a Navy Lieutenant. It consisted of a simple telescope containing a pair of crosshairs, and was mounted in such a way that the line of sight could be moved with respect to the axis of the gun to correct for some of the factors which affect the solution of the fire control problem.

RANGING DEVICES

Improvements in gun sighting systems alone were not enough, however, as the range and

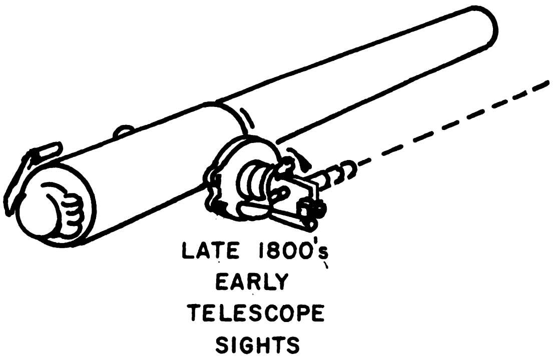

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Figure 1-1.—Early telescope sights.

complexity of guns increased. It became necessary to develop other fire control instruments which could accurately and rapidly solve the fire control problem.

The first of these devices was the stadimeter (fig. 1-2), an optical device used to measure range. This device enabled the gunner to determine the range more accurately than could be done by eye. The stadimeter was good only for short ranges, but embodied a principle later used in the rangefinder.

The rangefinder, developed during World War I, had a much greater range. Rangefinders are still installed on the older gun fire control systems.

STABILIZING METHODS

Another factor which had to be taken into consideration to obtain accurate fire was the inclination of the gun caused by the roll and pitch of the ship's deck. One early device used by nautical gunners was a round shot suspended from a spar (fig. 1-3). The gunner watched this improvised pendulum and fired his gun just before it was parallel to the mast (when the deck was horizontal). This same principle was later incorporated in the "stable element" and the "ship's gyro." These devices act like a child's spinning top, in that their axes always remain truly vertical, thus establishing a reference plane from which gun elevation angles can be measured.

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Figure 1-2.—The stadimeter.

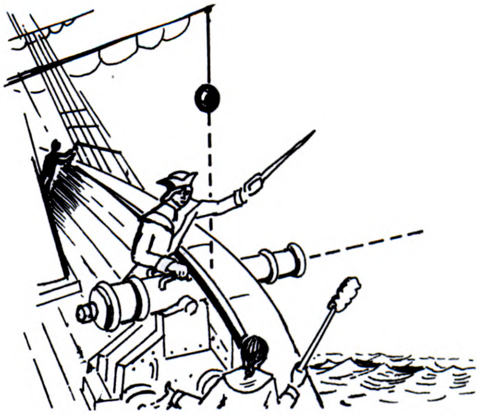

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Figure 1-3.—Correcting for roll and pitch.

TRACKING METHODS

The largest and most important corrections in fire control are to compensate for the relative motion between gun and target. In the old days, the positions of the gun and the target at the moment of impact of the projectile were predicted by eye. In the early 1900's, an improvement was brought about by marking the position of the target on paper (plotting) as it moved along its course. (This was done by measuring the distance and direction from the ship to the target). It was then possible to determine the approximate course and future position of the target (fig. 1-4). This led to the

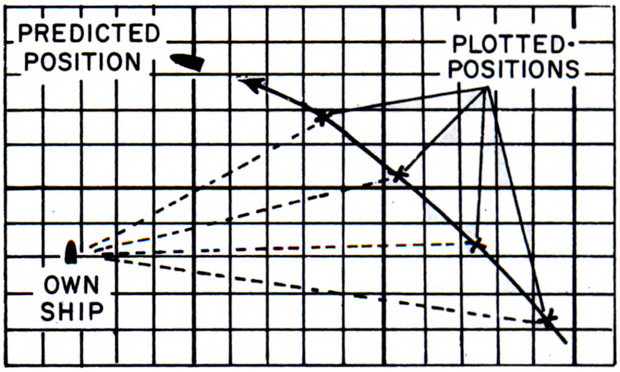

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Figure 1-4.—Target plotting.

development of the rangekeeper, a device which automatically corrected for changes in target range. The rangekeeper was refined and improved till it reached its present form, the fire control computer, and made possible the rapid solution of other factors in the fire control problem.

The most important World War II fire control innovation was radar, which made accurate fire control possible even when optical instruments were useless.

FIRE CONTROL TODAY

Today, fire control systems are used to control not only guns, but also missiles, rockets, and torpedoes.

However, the basic idea of a gun or missile weapon system does not change. They all need certain components in order to operate as a complete system.

Figure 1-5 shows the basic components that may be found in any missile weapon system.

Weapon Direction System

The Weapon Direction System (WDS) provides for the centralized control and monitoring of target engagements. It is used to initially evaluate targets, assign the targets to the missile fire control system, select and control the firing of missiles, and evaluate the engagement results.

Radar/Director

The function of the radar/director is to locate the position of a target. You may think of it as the eyes of the fire control system. The radar/director tracks the target and provides precise position data to the computer.

Computer

Fire control computers are the brains of the system. When they are supplied with the data needed to solve the fire control problem, the computers yield solutions in the form of

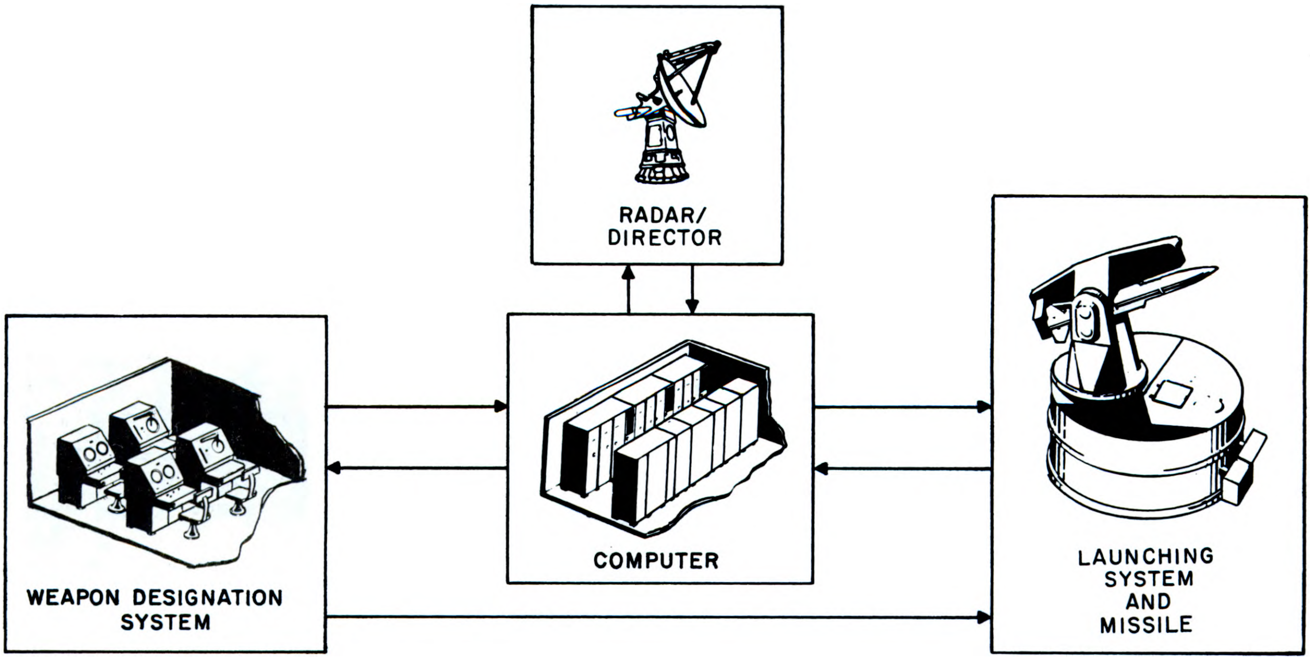

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Figure 1-5.—Typical missile weapon system.

position and control signals for the launcher and missile.

Launching System

The launching system is comprised of a launcher and a magazine. The launcher is a structure that supports the missile for firing. It is movable and provides a means for aiming the missile. Data for the missile is also inserted through the launcher. The magazine stores the missile until needed. Some launchers double as magazines, and the missile is fired directly from its storage cell.

Missile

The missile is the destructive unit which carries the explosive to the target. Let us now look at the missile as it developed from the early cannonball to the sophisticated weapon we have today.

EVOLUTION OF THE GUIDED MISSILE

A MISSILE is any object that can be launched or thrown at a target. This includes stones or arrows as well as gun projectiles, bombs, torpedoes, and rockets. In current military use, the word MISSILE is becoming synonymous with GUIDED MISSILE. In this text, we will use the terms MISSILE and GUIDED MISSILE interchangeably.

THE PURPOSE OF GUIDED MISSILES

The primary mission of the Navy is control of the seas. We propose to keep the sea-lanes open for our own and for friendly commerce. In time of war, we propose to deny the use of the sea to the enemy. With the advent of the Polaris family of missiles, we have an added use for the sea—a hiding place for our most potent seaborne defenses.

Historically, the Navy's mission has been accomplished by the use of warships that were armed with the most advanced weapons of their time. When John Paul Jones challenged the British control of the seas, his warships carried guns that had an effective range of a few hundred yards. In the Civil War, the Union Navy kept up a blockade of southern ports with the help of guns that had a range of 5 to 10 miles.

When aircraft became more effective weapons than guns, in both range and striking power, they became the prime weapons of the Navy. The battle of the Coral Sea, in 1942, was the first major naval battle in which ships did not exchange a single shot.

The development of missiles added a new dimension to the attack or defense mission. Missiles cannot perform all the functions of guns. But, they can extend the range and effectiveness with greater payloads. Even without control of the sea's surface, missiles can be launched from submarines.

The effort to develop faster and better missiles will continue as long as the threat of war exists, or until some new and unforeseen weapon makes guided missiles obsolete.

NAVY SURFACE MISSILE SYSTEMS

In 1944, the Navy assigned development of the Bumble-bee project to the Applied Physics Laboratory of the Johns Hopkins University. This project has since produced TERRIER, TARTAR, STANDARD, and the now obsolete TALOS missiles. These surface-to-air missiles greatly improved the Navy's fleet antiaircraft defenses.

In the early 1960's, a need was recognized for a rapid reaction, lightweight surface-to-air missile system that could provide a self-defense capability against the fast growing threats of the future. (The TARTAR, TERRIER, and TALOS weapon systems were developed to provide protection of the area around fleet units.) What was needed was a system to protect the "point-of-origin" or an individual ship at close-in ranges. The basic, and later the improved, Point Defense Missile Systems were developed to meet that need. These systems use a SPARROW III air-to-air missile which was modified for surface launch.

In the late 1970's, the HARPOON antiship missile was introduced. It uses an over-the-horizon concept which further enhances fleet defense. All of these missiles which are currently used by the Navy, and their updated versions, will be discussed in more detail in the next chapter.

New missiles are still being designed and tested for surface fleet use. Among these are the long-range cruise missile (TOMAHAWK) and the rolling airframe missile (RAM). The TOMAHAWK uses terrain matching or radar homing devices against land and ship targets, respectively. The RAM will provide quicker reacting, close-in self-defense for vital fleet units. It uses dual-mode (infrared and rf) homing and an automatic launching system.

A major development in fleet defense is the AEGIS weapon system, which is a fully automatic surface-to-air missile system. The heart of the system is the AN/SPY-1A multifunction, phased array radar system. It simultaneously performs horizon search, hemispherical search, multiple target tracking and multiple interceptor missile tracking. It also provides missile guidance commands and target kill evaluation. This computer controlled, automated system provides an unprecedented short reaction time and potent firepower. The AEGIS weapon system employs STANDARD missiles.

CHAPTER 2

THE GUIDED MISSILE

This chapter presents the physical and functional characteristics of guided missiles. The information is presented at an elementary level and, for the most part, is applicable to all guided missiles. Be aware, however, that you are striving for knowledge of the basic principles and concepts underlying the operation of missiles employed by the Surface Missile Systems (SMS) of the Navy. Therefore, the focus of attention is directed toward SMS missiles.

After studying this chapter, you will know what a guided missile is, how it is classified, and how it is guided, stabilized, and propelled. You will know the essential components required for a guided missile to perform its mission. Finally, you will know the missiles that make up the SMS family of missiles.

MISSILE FUNDAMENTALS

Any object that can be hurled, projected, launched, or propelled into flight may be called a missile. This definition includes stones, arrows, projectiles, bombs, torpedoes, rockets, and airplanes. The scientific progress made in rocketry, jet propulsion, electronics, and aerodynamics not only has increased the range of the missile, but now allows it to be controlled or guided in its flight. A tactical guided missile carries an explosive warhead and some means of controlling its own trajectory or flight path.

Generally, a guided missile system is considered to have five subsystems. These are the air frame (structure), propulsion, flight control, guidance, and warhead subsystems.

The warhead is the primary subsystem of the missile (considering the missile itself to be the overall system). This is because the end result (target kill) is accomplished directly by its destructive energy output. The main missile structure is the body or fuselage which not only carries and protects the warhead and other components from the forces or pressures that will be exerted on them, but which also has aerodynamic surfaces attached to it that are used to stabilize the missile and to control its flight path. In addition, the structure contains a subsystem that controls these surfaces and a means of propulsion to move the missile from its launch point to its target. To correct for flight path errors and/or to allow the missile to seek out and destroy an enemy target, a guidance subsystem is added.

Missile subsystems are discussed more thoroughly later in this chapter. Before that, however, let us briefly consider the requirements of guided missiles, in general, and acquaint ourselves with the SMS missiles.

MISSILE REQUIREMENTS

Guided missiles were developed to overcome some of the limitations of older, established weapons, such as bombs and naval guns (artillery). The development of naval guns had reached a point where tremendous cost and effort were necessary in order to produce even minor improvements in their performance. This instigated, in large part, the research and development of guided missiles.

The primary mission of naval guns was and is the destruction of designated targets. This is also true for the guided missile. The following examples show some of the missions and the advantages of using guided missiles to fulfill these missions.

AIR-TO-SURFACE

Air-to-surface guided missiles are far superior to conventional bombs. The aircraft dropping bombs is limited in the performance of its mission by weather, interception by enemy aircraft, antiaircraft artillery, and, in some cases, the maneuvering of the target during the fall of the bombs. By building bombers that can fly higher and faster, antiaircraft artillery and fighter interception can be evaded; but the accuracy of the bombs would be greatly reduced, and the weather would have a greater effect. By replacing the bombs with guided missiles, which can be launched at greater ranges and which contain a guidance system that will direct the missile to its target or permit it to home on (seek out) the target regardless of weather or target maneuvers, the destructive effect can be greatly increased, and the danger of enemy countermeasures greatly reduced.

SURFACE-TO-AIR

Now consider your side of the problem. As an FTM, you are involved with missiles that are used primarily as surface-to-air weapons. Obviously, you want the operational capabilities of your ship's weapons to exceed those of the enemy. Aircraft, for example, must be destroyed before they reach their weapon-release range (called standoff range). Ship-launched guided missiles are greatly superior to antiaircraft guns in range, maximum altitude, and accuracy. As a result, they can destroy enemy aircraft beyond the range of a gun.

AIR-TO-AIR

In air-to-air combat, guided missiles greatly increase the striking range and destructive power of aircraft.

The interceptor aircraft of the past relied primarily on its speed advantage to maneuver into a position where its short-range weapons were effective. Against modern jet bombers or missiles, interceptors lose their speed advantage, thus making it difficult, if not impossible, for them to maneuver into position for attack. By arming them with long-range missiles which travel at supersonic speeds, interceptors are capable of combating the high-speed, high-altitude weapons of modern warfare.

SURFACE-TO-SURFACE

The average person, when thinking of a surface-to-surface missile, probably visualizes an intercontinental ballistic missile (ICBM), such as MINUTEMAN or the now obsolete TITAN with ranges in excess of 3000 nautical miles. The ICBMs are fine for their purpose. No one, however, would consider firing one at a target that was less than 50 miles away. A need, therefore, exists for a comparatively short-range surface-to-surface guided missile. The SMS missiles satisfy this need, as you will find out when SMS missile configurations are discussed at the end of this chapter. Until then, let's satisfy ourselves with a very brief introduction to the missiles.

SURFACE LAUNCHED MISSILES

The missiles that you, as an FTM, may be concerned with are the TARTAR, TERRIER, STANDARD (SM-1 and SM-2), SPARROW III, and HARPOON. As you will discover in the section describing SMS missile configurations, the actual missile or missiles with which you will be directly involved will depend upon the class of ship to which you are assigned.

The HARPOON is an antiship missile capable of being launched from an aircraft, a ship, or a submarine. The others are primarily surface-to-air missiles. They do, however, have surface-to-surface capability and, in some cases, a surface-to-shore capability. As indicated earlier, these will be more fully discussed later in the chapter.

Now, you know the names of the SMS missiles. This should prove beneficial, because frequent reference is made to them throughout this chapter. Following is an explanation as to how the missiles are identified.

MISSILE DESIGNATIONS

Military guided missiles of the United States are categorized according to the environment from which the missile is launched, the type of mission the missile is intended to perform, the missile type, the design number of the missile, and the series number of the missile. For example, referring to table 2-1, it can be

Table 2-1.—Missile Categories

LAUNCH ENVIRONMENT SYMBOLS

Letter	Title	Description
A	Air	Air launched.
B	Multiple	Capable of being launched from more than one environment.
C	Coffin	Stored horizontally or at less than a 45 degree angle in a protective enclosure (regardless of structural strength) and launched from the ground.
H	Silo Stored	Vertically stored below ground level and launched from the ground.
L	Silo Launched	Vertically stored and launched from below ground level.
M	Mobile	Launched from a ground vehicle or movable platform.
P	Soft Pad	Partially or nonprotected in storage and launched from the ground.
R	Ship	Launched from a surface vessel, such as ship, barge, etc.
U	Underwater	Launched from a submarine or other underwater device.

MISSION SYMBOLS

D	Decoy	Vehicles designed or modified to confuse, deceive, or divert enemy defenses by simulating an attack vehicle.
E	Special Electronic	Vehicles designed or modified with electronic equipment for communications, countermeasures, electronic radiation sounding, or other electronic recording or relay missions.
G	Surface Attack	Vehicles designed to destroy land or sea targets.
I	Intercept-Aerial	Vehicles designed to intercept aerial targets, defensive or offensive roles.
Q	Drone	Vehicles designed for target, reconnaissance, or surveillance purposes.
T	Training	Vehicles designed or permanently modified for training purposes.
U	Underwater Attack	Vehicles designed to destroy enemy submarines or other underwater targets or to detonate underwater.
W	Weather	Vehicles designed to observe, record, or relay meteorological data.

VEHICLE TYPE SYMBOLS

M	Guided Missile	Unmanned, self-propelled vehicles designed to move in a trajectory or flight path all or partially above the earth's surface and whose trajectory or course, while the vehicle is in motion, can be controlled remotely or by homing systems, or by inertial and/or programmed guidance from within. This term does not include space vehicles, space boosters, or naval torpedoes, but does include target and reconnaissance drones.
N	Probe	Non-orbital instrumented vehicles not involved in space missions that are used to penetrate the aerospace environment and report information.
R	Rocket	Self-propelled vehicles without installed or remote control guidance mechanisms, whose trajectory cannot be altered after launch. Rocket systems designed for line of sight are not included.

The military designation of the ASROC missile is RUR-5A since it is a ship launched rocket designed to destroy enemy submarines. It is the first (A) of its assigned design number (5).

If necessary, to denote a special status, one of the following letters is affixed before the military designation.

STATUS PREFIX SYMBOLS

J	Special Test (Temporary)	Vehicles especially configured simply to accommodate test.
N	Special Test (Permanent)	Vehicles so modified they will not be returned to original use.
X	Experimental	Vehicles under development.
Y	Prototype	Preproduction vehicles for test.
Z	Planning	Vehicles in planning stage.

167.702

determined that the RIM-2F is a ship-launched guided missile designed to intercept air targets. The missile design number is 2, and the F indicates that it is the sixth modification to that design.

Additional examples of missile designations are given in the section that describes SMS missile configurations. When you get to them, refer back to this table and see if you can categorize the missiles designated.

MISSILE SUBSYSTEMS

Earlier, you learned that guided missiles are made up of five main subsystems (fig. 2-1). The missile must have a body or basic structure; it must be propelled; it must sense deviations from its proper course; it must correct for those deviations; and it must carry a payload. The main body of the missile, which houses the other subsystems, is called the STRUCTURE, also commonly known as the airframe. The subsystem which moves or propels the structure is the PROPULSION SYSTEM, or power plant. The subsystems that make the missile a true guided missile are the GUIDANCE and CONTROL subsystems. Further, if the missile is to perform a useful military mission, it must contain a payload consisting of a WARHEAD and its fuzes.

Much of the remainder of this chapter discusses various types of these subsystems. To a considerable degree, much of the discussion serves as a basis for future study. Also, many of the terms applied to guided missiles are introduced.

WARHEADS

The warhead effectively destroys a target or target area by converting stored chemical or nuclear energy into destructive force; by producing high velocity fragments; by creating blast effects of tremendous potential; or by releasing radioactive agents into the atmosphere.

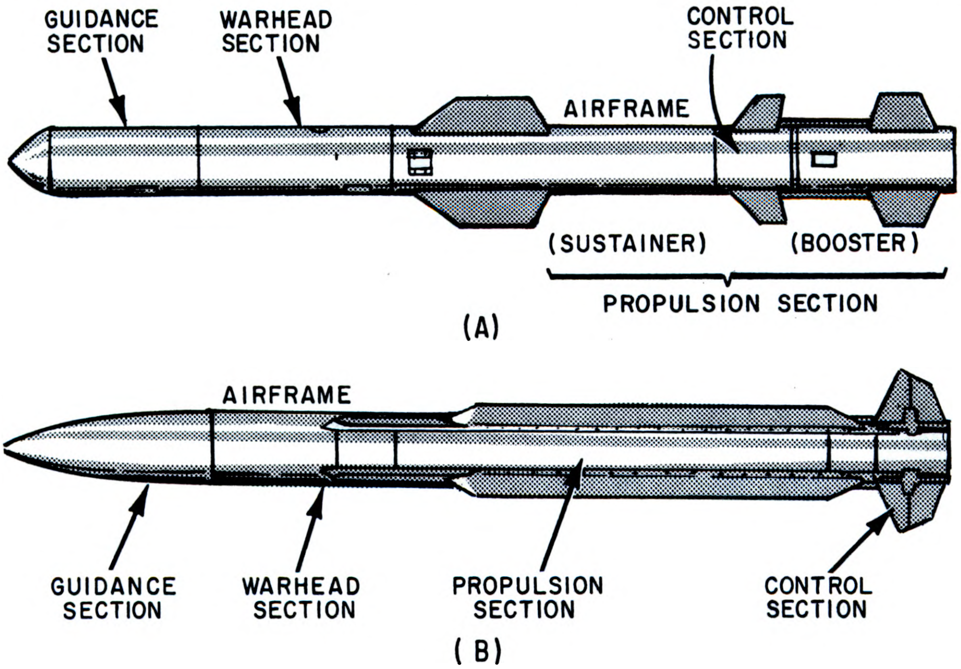

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Figure 2-1.—Location of principal components: A. HARPOON missile; B. STANDARD missile.

The warhead incorporates a fuze device that recognizes or senses the best time for detonation, and a safety and arming (S&A) element that prevents early detonation by preventing warhead arming until the missile is a safe distance from the ship firing it.

STRUCTURE

The structure contains, supports, and protects the warhead and other subsystems during launch and travel to the target. It supports and protects the propulsion, guidance, and flight control subsystems; provides external control surfaces that permit guidance signals to initiate flight path control action; and is designed to allow smooth flight through the atmosphere.

PROPULSION

The propulsion subsystem provides the power or energy necessary to propel or move the missile to the target.

Increased propulsion may be achieved by the use of more than one propulsion unit. For example, a booster rocket may be employed to accelerate a missile to a desired flight speed prior to the operation of a sustainer engine. Once it has expended its propelling force, the booster separates from the missile, as shown in figure 2-2. The sustainer engine then takes over and provides the propelling force necessary to maintain the speed of the missile.

CONTROL

To intercept and destroy a target, a guided missile must follow a desired flight path. Control of the missile requires it maintain a stable attitude while in flight and that it correct for flight path errors detected by its guidance system. Normally, control devices, preset before launch, are used for the control of missile stability. The flight path errors may be the result of initial incorrect computations, subsequent target maneuvers, natural forces or any combination of these factors. Signals from both the control devices and the error sensing device

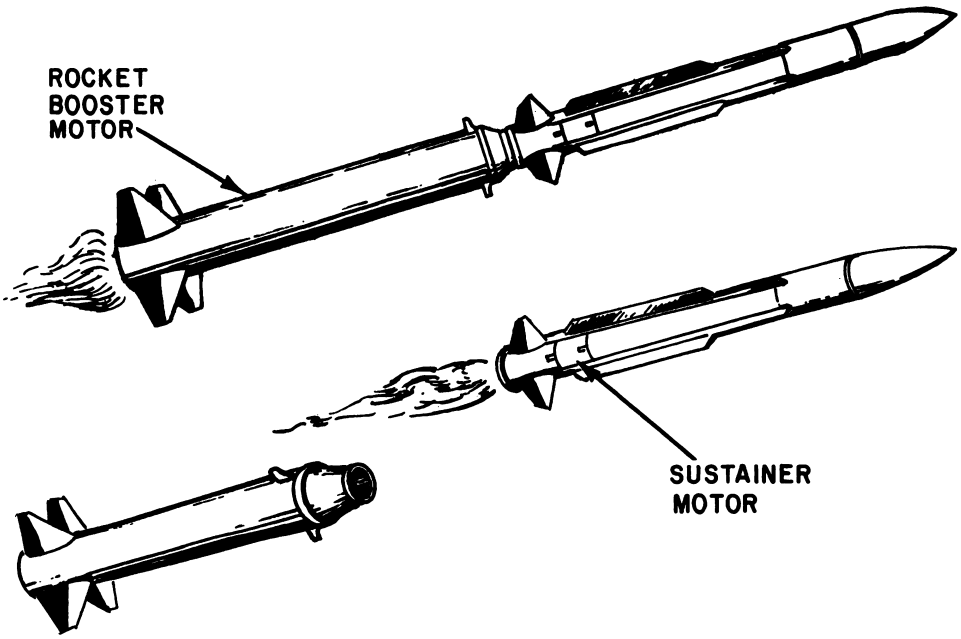

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Figure 2-2.—Booster rocket separation.

are used as inputs to the missile's control subsystem. The control subsystem is used to position the missile's control surfaces (wings and/or fins).

The moveable control surfaces react with air, according to the laws of aerodynamics, to control a missile in flight. The control surfaces may be located in any position, depending on the mission and design requirements. Examples of control surface configurations and locations are shown in figure 2-3.

GUIDANCE

A guidance subsystem senses the missile position with respect to its target and initiates action to correct any deviation from the flight path required to intercept the target. A guidance subsystem may alter the course during flight in response to target data or exterior inputs, such as commands or radar beam directional shifts. There are many types of guidance subsystems in use, each classified by means of the method used to sense position.

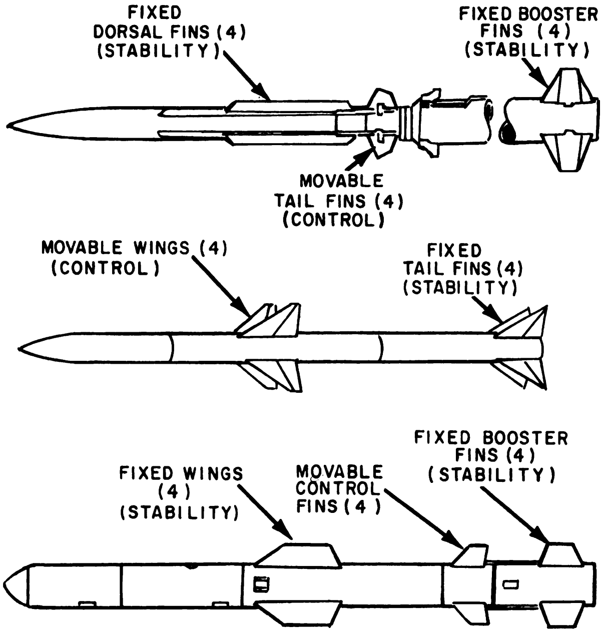
FIXED DORSAL FINS (4) (STABILITY)
FIXED BOOSTER FINS (4) (STABILITY)
MOVABLE TAIL FINS (4) (CONTROL)
MOVABLE WINGS (4) (CONTROL)
FIXED TAIL FINS (4) (STABILITY)
FIXED BOOSTER FINS (4) (STABILITY)
FIXED WINGS (4) (STABILITY)
MOVABLE CONTROL FINS (4)
144.2

Figure 2-3.—Control surface configurations and locations.

The type of guidance subsystem most often used by SMS missiles is homing. Beam-riding, command, and inertial guidance are also used, but to a lesser extent. With homing, the missile seeks the target by responding to signals that come from, or are reflected from, the target. Beam-rider missiles follow a narrow radar beam that is controlled by the launch ship. Missiles that employ inertial guidance respond to self-contained devices that control the missile's flight path. Missiles employing command guidance respond to radio or radar signals from the launching ship. Some missiles employ combinations of all types of guidance.

Missile guidance is described in greater detail later in this chapter. Before covering that, however, the types of warheads and fuzes used by SMS missiles will be discussed.

TYPES OF WARHEADS AND FUZES

The guided missile must carry some form of useful burden—a payload—if it is to accomplish its mission. Every action of the missile serves as a means to deliver its payload. In exercise missiles, the payload often includes telemetering units, which collect data during the flight, convert it into radio signals, and transmit the information to receivers at land stations or aboard ship. The exercise missiles may carry dummy payloads and tactical fuzes which have the same physical characteristics as an operational weapon. In its military role, the guided missile's payload consists of one or more WARHEADS and one or more FUZES. The warhead is capable of destroying an enemy target. The fuze is a triggering mechanism used to initiate the actions of the warhead.

The basic warhead subsystem consists of three functional parts: a payload, a fuze, and a safety and arming (S&A) device. Variations in types of warheads are obtained by altering any single element or even all three elements.

Some of the types of warheads that may be used in guided missiles are blast-effect, fragmentation, shaped-charge, explosive-pellet, and nuclear or thermonuclear.

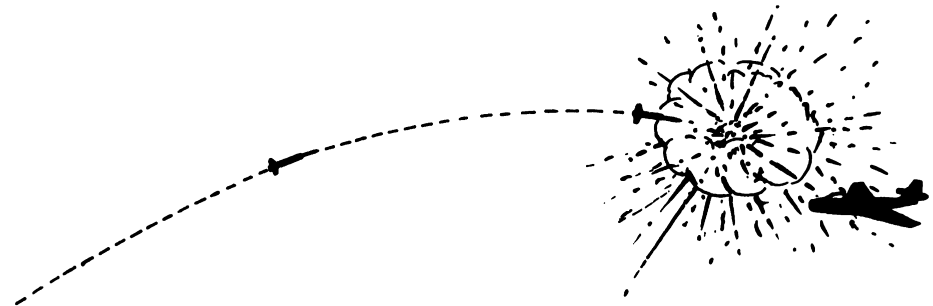

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Figure 2-4.—Effect of fragmentation warhead.

PAYLOAD

The primary element of the warhead is the payload, defined as the destructive agent of the warhead, or that portion of the warhead which accomplishes the desired end result.

Blast-Effect Warheads

This type of warhead causes damage by means of a high-pressure wave or blast, which results from the detonation of high-explosive material. Blast warheads are very effective against ground and surface targets. They are less effective against aerial targets since the pressure wave dissipates rapidly in air. The HARPOON missile uses a blast type of warhead.

Fragmentation Warheads

These warheads operate by bursting a metal case containing a high-explosive charge. Upon explosion, the container is shattered into hundreds of fragments which fly out at high velocities. The fragments are capable of damaging targets at considerable distances from the point of detonation (fig. 2-4). For this reason, this sort of warhead is very effective against aerial targets. Usually the warhead does not penetrate the target but is detonated by the fuze at a distance which allows the full destructive effect to be realized. This is the type most commonly used with antiaircraft gun ammunition. Sometimes the fragmentation pattern is controlled, or directional. When the pattern is controlled, it is more effective against stationary targets or slow-moving surface craft.

The continuous-rod warhead (fig. 2-5) is a controlled fragmentation type of warhead used extensively on SMS missiles. TARTAR, TERRIER, STANDARD, and SPARROW III all have continuous-rod warheads. Upon detonation, the continuous-rod warhead expands radially into a ring pattern. The intent is to cause the connected rods, during their expansion, to strike the target and produce damage by a cutting action as shown in figure 2-5.

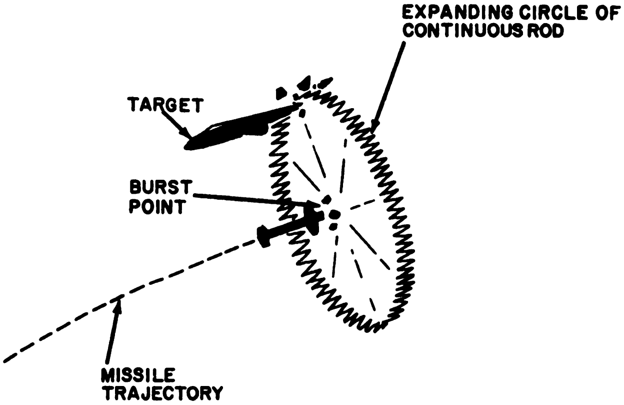

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Figure 2-5.—Expansion of Continuous-rod warhead.

Nuclear and Thermonuclear Warheads

In this type of warhead, destruction and damage result from the processes of atomic fission or fusion. The destructive effects are blast, heat, and radiation. The detonation results in death, sickness, and the denial of the use of large areas as a result of the release of radioactive elements.

Other Types of Warheads

There are many other types of warheads used with other Navy missiles. These include shaped-charge and explosive-pellet. They are not, however, used with SMS missiles.

FUZES

The fuze is that part of the warhead which initiates detonation of the payload. In guided missiles, the fuze is referred to as the target detecting device (TDD).

For an attack to be effective, detonation must occur at the time during the missile's flight that will cause maximum damage to the target. Called the "optimum time of detonation," it is determined by the nature of the target and the attack angle involved. If effectively designed, the fuze will always recognize and initiate detonation at this optimum time.

The optimum time of detonation is computed from data concerning the target's location and movement relative to the missile. The data may be derived from energy which is either generated or influenced by the target, or from the acceleration motion of the missile. The fuze may perform this data-gathering function independently or may be supplied with the required data by a central data-gathering system which also supplies data to other components of the missile, such as the guidance system.

The missile warhead is activated by the actions of one or more fuzes, which release the destructive forces after certain conditions have been fulfilled. The type of fuzing employed determines whether the warhead is detonated at a distance from the target (proximity), upon impact with it (non-delay), or at some fixed time after penetration of the target skin (time-delay). These situations are illustrated in figure 2-6.

The most effective type of fuze for a given missile depends upon the nature of the target and the probability of the warhead causing damage. The types often employed in missiles are the IMPACT, GROUND-CONTROLLED, and PROXIMITY fuzes.

Impact Fuzes

Impact fuzes are actuated by the inertial force exerted when the missile strikes the target. If detonation takes place at the moment of impact, the fuze is of the NON-DELAY, or INSTANTANEOUS type. If the detonation takes place some time after penetration, the fuze is said to be of the DELAY type.

Ground-Controlled Fuzes

In ground-controlled fuzes, some device is used for measuring the distance from the missile to the target. The control device is not mounted in the fuze but on the ground, and when the proper space relationship exists between the missile and its target, a signal is sent to detonate the fuze from the control point on the ground.

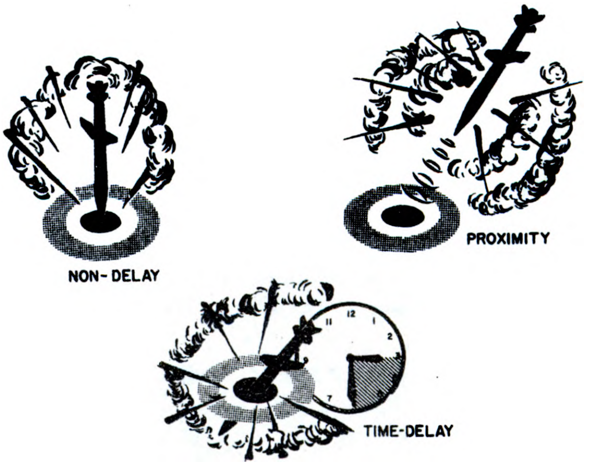

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Figure 2-6.—Types of fuzing.

Proximity Fuzes

Fuzes of this type are actuated by some characteristic feature of the target or target area. They are designed so that the warhead burst pattern will occur at the most effective time and place relative to the target. The most effective type uses a radio transmitter and receiver, normally called a target detecting device (TDD).

In operation, the TDD transmitter transmits an rf signal in the direction of the target. The transmitted signal hits the target and is reflected back to the receiver of the TDD. From the reflected signal, closing rate and distance can be determined. When the missile is at the proper distance from the target, warhead detonation is initiated. Hopefully, the proper distance is the optimum distance for destruction of the target.

SAFETY AND ARMING

The safety and arming (S&A) device performs two separate functions within the warhead. First, it prevents accidental detonation of the warhead (safety feature) by interrupting the path between the fuze and the payload until it is ascertained that detonation will not be dangerous to the firing ship. Secondly, it provides a detonation path (arming feature) between the fuze and the payload, after safety has been assured, by removing the interruptor. The S&A device thus acts as an open switch until safe detonation can be accomplished, and is then closed. Normally, an acceleration arming device is used to assure the safety function. This device senses changes in velocity. (The changes are normally referred to as accelerations.)

With S&A devices of this type, there must be both a missile acceleration and an acceleration decay (after booster burnout) to arm the warhead. The intent is to keep the warhead from being armed until safety permits it.

Now, we are ready for a discussion of missile guidance. This is a basic discussion, divided into three parts—the phases of missile flight, the types of missile guidance, and the different missile flight paths. We will begin with a very broad overview of missile guidance.

MISSILE GUIDANCE

The purpose of a guidance subsystem is to direct the path of the missile to target intercept regardless of whether or not the target takes deliberate evasive action. The guidance function may be based on information provided by a signal from the target, on information sent from the launching ship, or both.

Every missile guidance system consists of two separate systems—an attitude control system and a flight path control system. The attitude control system maintains the missile in the desired attitude on the ordered flight path by controlling the missile in pitch, roll, and yaw (fig. 2-7). This action, along with the thrust of the rocket motor, keeps the missile in stabilized flight.

The flight path control system guides the missile to its designated target. This is done by determining the flight path errors, generating the necessary orders needed to correct these errors, and sending these orders to the missile's control subsystem. The control subsystem exercises control in such a way that a suitable flight path is achieved and maintained.

The operation of the guidance and control subsystems is based on the closed-loop or servo

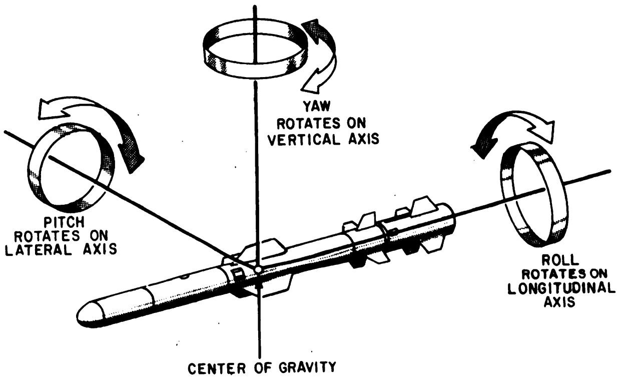

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Figure 2-7.—Missile axes: pitch, roll, and yaw.

principle, (fig. 2-8). The control units make corrective adjustments to the missile control surfaces when a guidance error is present. The control units also adjust the wings and/or fins to stabilize the missile in roll, pitch, and yaw. Guidance and stabilization are two separate processes, although they occur simultaneously.

PHASES OF GUIDANCE

Missile guidance is generally divided into three phases, (fig. 2-9A). As indicated in the figure, the three phases are boost, midcourse, and terminal. STANDARD SM-2 missiles (MR & ER) utilize all three of these phases. Not all missiles, however, go through the three phases. As shown in figure 2-9B, some missiles (STANDARD SM-1, TARTAR, TERRIER and SPARROW III) do not use midcourse guidance. With that thought in mind, let's examine each phase, beginning with boost.

Initial (Boost) Phase

Navy surface-launched missiles are boosted to flight speed by means of the booster component (which is not always a separate component) of the propulsion system. This boost period lasts from the time the missile leaves the launcher until the booster burns up its fuel. In missiles with separate boosters, the booster drops away from the missile at burnout (fig. 2-9A). Discarding the burnt-out booster shell reduces the drag on the missile and enables the missile to travel farther. The SMS missiles with separate boosters are TERRIER, STANDARD (ER), and HARPOON.

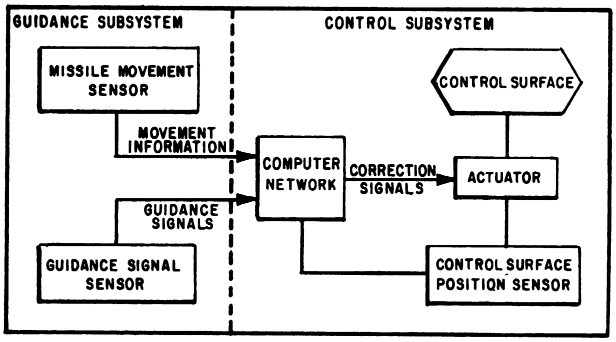

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Figure 2-8.—Basic missile guidance and control subsystems.

The problems of the initial phase and the methods of solving them vary for different missiles. The method of launch is also a factor. The basic purposes, however, are the same. The launcher, holding the missile, is aimed in a specific direction on orders from the fire control computer. This establishes the line of fire (trajectory or flight path) along which the missile must fly during the boosted portion of its flight. At the end of the boost period, the missile must be at the precalculated point.

There are several reasons why the boost phase is important. If the missile is a homing missile, it must "look" in a predetermined direction toward the target. The fire control computer (on the ship) calculates this predicted target position on the basis of where the missile should be at the end of the boost period. Before launch, this information is fed into the missile.

When a beam-riding missile reaches the end of its boosted period, it must be in a position where it can be captured by a radar guidance beam. If the missile does not fly along the prescribed launching trajectory as accurately as possible, it will not be in position to be captured by the radar guidance beam to continue its flight to the target. The boost phase guidance system keeps the missile heading exactly as it was at launch. This is primarily a stabilizing function.

During the boost phase of some missiles, the missile's guidance system and the control surfaces are locked in position. The locked control surfaces function in much the same manner as do the tail feathers of a dart or arrow. They provide stability and cause the missile to fly in a straight line.

Midcourse Phase

Not all guided missiles have a midcourse phase, but when present, it is often the longest in both time and distance. During this part of

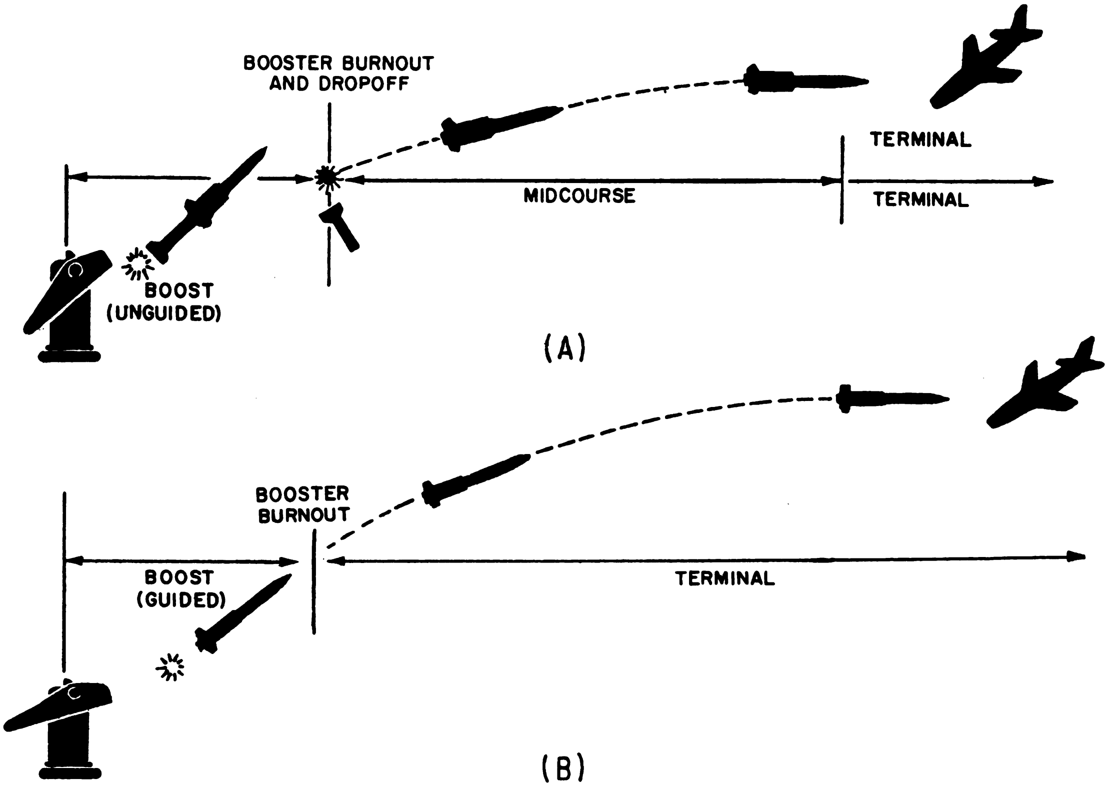

Figure 2-9.—Guidance phases of missile flight.

flight, changes may be needed to bring the missile onto the desired course and to make certain that it stays on that course. In most cases, midcourse guidance is used to put the missile near the target, where the final phase of guidance can take control. The HARPOON and STANDARD SM-2 missiles use a midcourse phase of guidance.

Terminal Phase

The terminal or final phase is of great importance. The last phase of missile guidance must have a high degree of accuracy, as well as fast response to guidance signals to ensure an intercept. Near the end of the flight, the missile may be required to maneuver to its maximum capability in order to make the sharp turns needed to overtake and hit a fast-moving, evasive target. In some missiles, maneuvers are limited during the early part of terminal phase. As the missile gets closer to the target, it becomes more responsive to the detected error signals. In this way, excessive maneuvers are avoided during the first part of terminal phase.

TYPES OF GUIDANCE

As mentioned earlier, missiles have a path control system and an attitude control system. Guidance systems are usually classified according to their path control system, since many missiles use the same type of attitude control. The type of attitude control used in the SMS fleet is inertial. The following is a discussion of the types of path control (guidance) in use in SMS missiles.

Inertial Guidance

An inertial guidance system is one that is designed to fly a predetermined path. The missile is controlled by self-contained automatic devices called accelerometers. Accelerometers are inertial devices that measure accelerations. In missile control, they measure the vertical, lateral, and longitudinal accelerations of the controlled missile (fig. 2-10). Although there may not be contact between the launching site and the missile after launch, the missile is able to make corrections to its flight path with amazing precision.

During flight, unpredictable outside forces, such as wind, work on the missile, causing changes in speed and direction. These changes are continuously measured by the accelerometers, which are usually mounted on a gyro-stabilized platform. As changes are sensed, the missile's computer, which is programmed prior to launch, generates correction signals to keep the missile on the proper flight path to the target.

An advantage of this type of system is that the missile is not dependent upon the tracking of the target after launch. This frees the tracking radar for other targets. Also, there are no existing countermeasures that could interfere with the missile's operation.

The HARPOON and STANDARD SM-2 missiles use this type of guidance for their midcourse phase.

Command Guidance

The term COMMAND is used to describe a guidance method in which guidance instructions, or commands, come from sources outside the missile. These commands are sent via radar or radio signals from a ship, a ground station, or an aircraft. The missile receiver is capable of extracting the guidance information and converting it into steering signals or control functions, such as arming, warhead detonation, or command destruction.

Figure 2-11A gives you an idea of how radar/radio command guidance works. The target is tracked while the missile sends its own position, direction, and speed via radio downlink. Target and missile data are sent to a shipboard computer to generate guidance commands. These commands are transmitted to the missile by varying the characteristics of the missile tracking or guidance beam, or by the use of a separate radio uplink transmitter.

Beam-Rider Guidance

A beam-rider guidance system is a type of command guidance in which the missile seeks

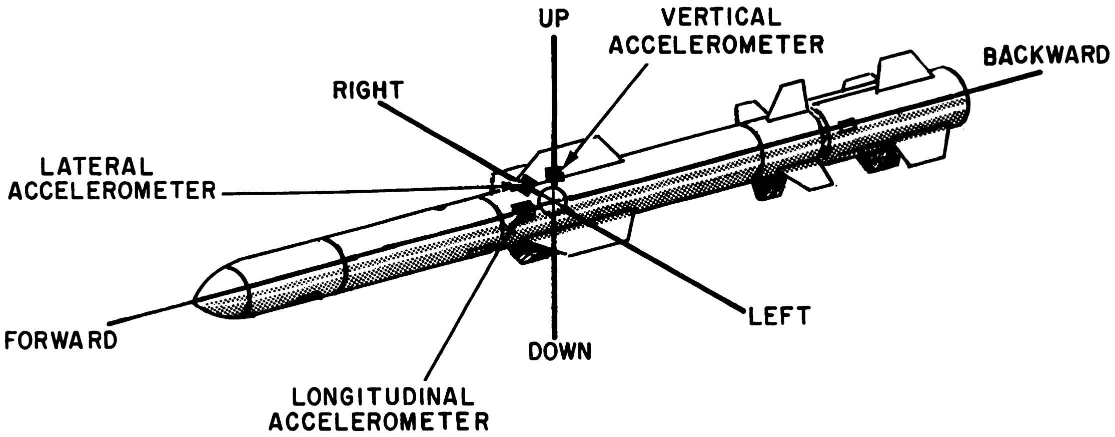

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Figure 2-10.—Accelerometers in a guided missile.

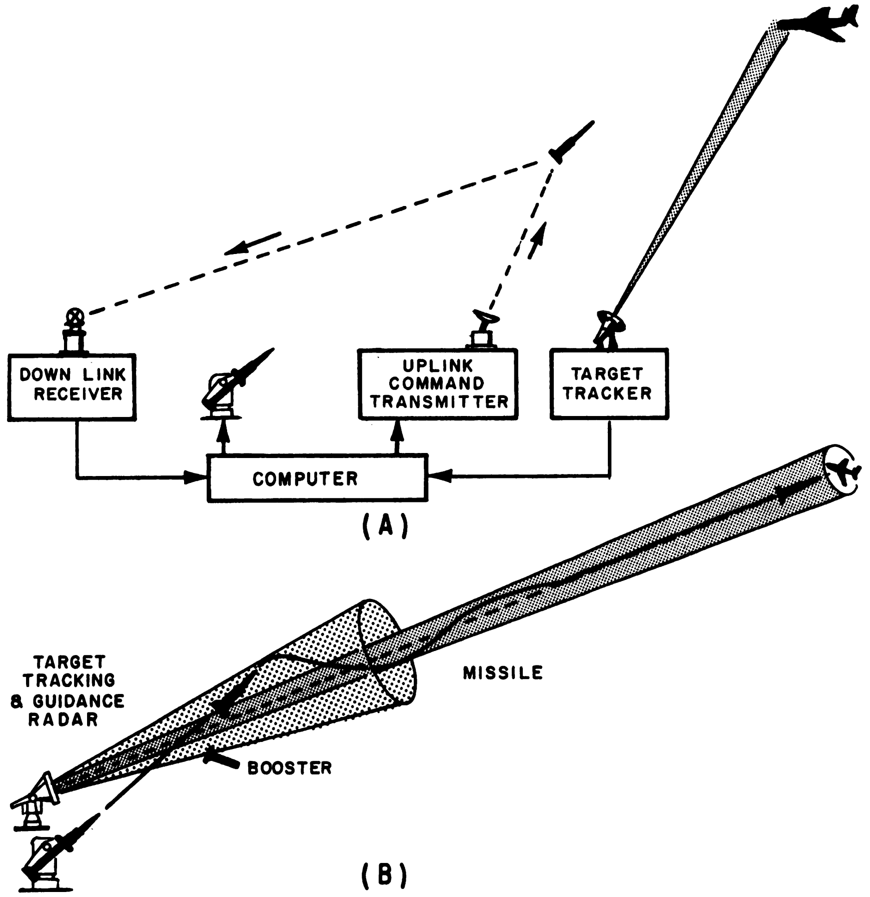

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Figure 2-11.—Simplified Command guidance systems: A. Radar/radio Command; B. Beam Rider.

out the center of a controlled directional energy beam. Normally, this is a narrow radar beam. Information as to the position of the missile within the beam is received by the missile guidance system. The guidance system interprets the information and generates its own correction signals, which cause the missile to remain in the center of the beam. The fire control radar keeps the beam pointed at the target and the missile "rides" the beam to the target. Figure 2-11B illustrates a simple beam rider guidance system. Because the beam spreads out, it is more difficult for the missile to sense and remain in the center. For this reason, the accuracy of the beam-rider decreases as the range between the missile and the ship increases. If the target is crossing (not heading directly at the firing ship), the missile must follow a continuously changing path. This may cause excessive maneuvering, which reduces the missile's speed and range. Beamriders therefore, are, effective against only short- and medium-range incoming targets.

Homing Guidance

Homing guidance systems control the path of the missile by means of a device in the missile that detects and reacts to some distinguishing feature of or signal from the target. This may be in the form of light, radio, heat, or sound waves or even a magnetic field. The SMS homing missiles use radar or rf waves to locate the target, while air-to-air missiles sometimes use infrared (heat) waves.

Since the system tracks a characteristic of the target or energy reflecting off the target, contact between the missile and target is established and maintained. The missile derives guidance error signals based on position relative to the target. This makes homing the most accurate type of guidance system, which is of great importance against moving air targets.

Homing guidance methods are normally divided into three types: ACTIVE, SEMIACTIVE, and PASSIVE (fig. 2-12).

ACTIVE HOMING.—With active homing, the missile contains both a radar transmitter and a receiver. The transmitter radiates rf energy in the direction of the target (fig. 2-12A). The rf energy strikes the target and is reflected back to the missile. (This process is referred to as "illuminating the target.") The missile seeker (receiving) antenna detects the reflected energy and provides it as an input to the missile guidance system. The guidance system processes the input, usually called the homing error signal, and develops target tracking and missile control information. Missile control causes the missile to fly a desired flight path.

The effective range of the missile transmitter is somewhat limited due to its size (power output). For this reason, relatively long-range missiles, such as HARPOON, do not switch to active guidance until after midcourse guidance has positioned the missile so that the transmitter is within its effective range.

SEMIACTIVE HOMING.—In a semiactive homing system, the target is illuminated by a transmitter (an illuminator) on the launching site (fig. 2-12B). As with active homing, the transmitted rf is reflected by the target and picked up by the missile's receiver. The fact that the transmitter's size is not limited, as with active homing, allows a much greater range.

The missile, throughout its flight, is between the target and the radar that illuminates the target. It will receive radiation from the launching ship, as well as reflections from the target. The missile must therefore have some means of distinguishing between the two signals, so that it can home on the target rather than on the launching ship. This can be done in several ways. For example, a highly directional antenna may be mounted in the nose of the missile. Or the doppler principle may be used to distinguish between the transmitter signal and the target echoes. Since the missile is receding from the transmitter and approaching the target, the echo

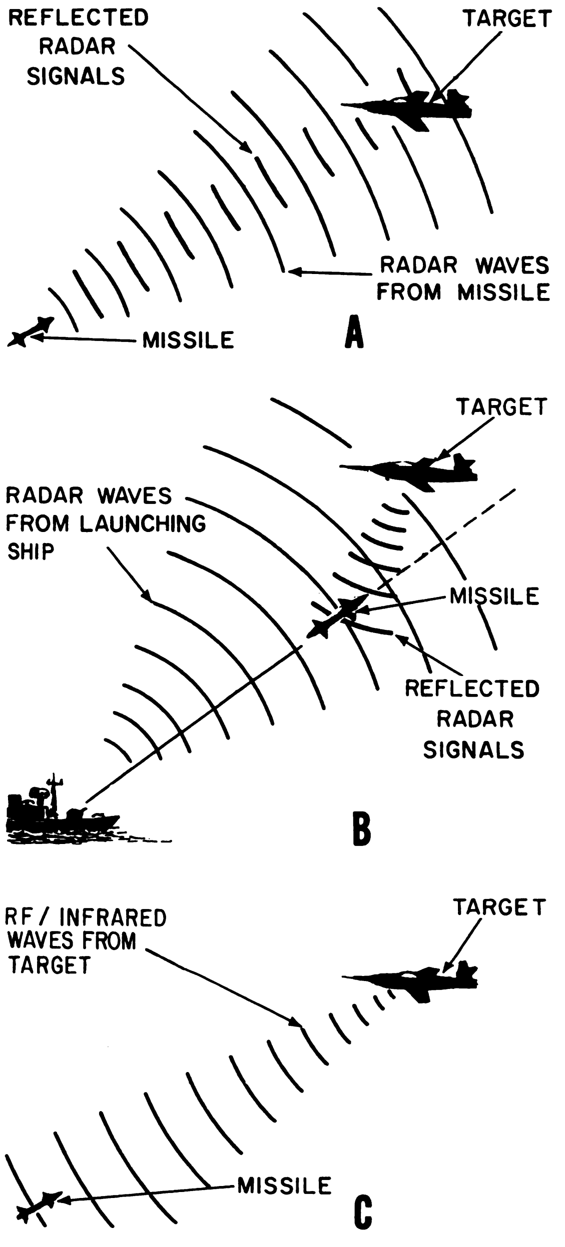

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Figure 2-12.—Homing guidance: A. Active homing; B. Semiactive homing; C. Passive homing.

signals will be of a higher frequency. Most SMS missiles use both of these methods.

A drawback of this system is that the shipboard illumination is not free to engage another target while the missile is in flight. TARTAR, TERRIER, STANDARD SM-1, and SPARROW III all use semiactive homing as their primary guidance; they do not use midcourse guidance. The STANDARD SM-2 uses midcourse guidance, and then semiactive homing only for terminal guidance. As a result, the SM-2 needs illumination from the ship only for the last few seconds of flight.

PASSIVE HOMING.–Passive homing requires that the target be a source of radiated energy (fig. 2-12C). Typical forms of energy used in passive homing are heat, light, and rf energy. One of the most common uses of passive homing is with air-to-air missiles that use heat-sensing devices. It is also used with missiles that home on rf energy that originates at the target (ships, aircraft, shore-based radar, etc.) An example of this is the STANDARD ARM (antiradiation missile) used for both air-to-surface and surface-to-surface engagements. An advantage of this type of homing is that the target cannot detect an attack because it does not get illuminated.

Several missiles that normally use other homing methods (active or semiactive) are capable of switching to passive home-on-jamming (HOJ) mode when in a countermeasure environment. That is, if the target detects that it is being illuminated by an active or semiactive guidance radar and initiates jamming (rf interference), the missile will home on the jamming signal if unable to maintain track on the reflected illumination signal.

MISSILE FLIGHT PATHS

As defined at the beginning of this chapter, a guided missile is one that is capable of controlling its own trajectory or flight path. There are many factors that may affect the path that the missile flies to the target. They may be natural, such as wind or gravity or man-made forces. Natural forces cannot be fully controlled, but they can be, to a great degree, predicted and, in turn, compensated for. Man-made factors, such as rocket-thrust and steering, can be controlled. Guided flight paths are usually categorized as either preset or variable. Some missiles use one type of path while other missiles may use a certain type for one phase of flight and another type for a different phase of its flight.

Preset Guided Paths

A preset path is one that has been fixed before launching. A simple type is a CONSTANT preset path that does not change during the time it is utilized. A more complex type is the PROGRAMMED preset that can change its path several times. Adjustment is accomplished by changing the altitude, heading, or angle of attack. A good example of the programmed preset flight path is the HARPOON's flight path (fig. 2-13), which

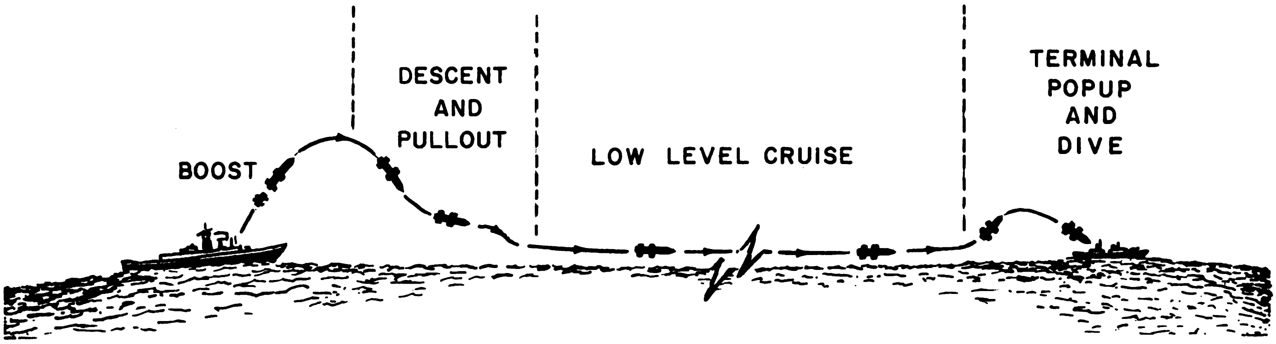

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Figure 2-13.–Programmed preset flight.

consists of several programmed maneuvers that vary the altitude and angle of attack.

Variable Guided Paths

A variable guided missile path is one that can be changed during flight, either by command of the launching ship (beam riding), or in response to new target data received by the missile. When a missile path is determined by target data received directly from the target by the missile, the missile is said to be "homing". Homing missiles use one of two methods in approaching a moving air target: a PURSUIT path or a COLLISION path. Beam riders use the LINE-OF-SIGHT path.

PURSUIT.–The simplest procedure for a guided missile to follow is to remain pointed at the target at all times. If the missile and target are approaching head-on, or if the missile is engaged in a tail chase, the pursuit curve is a straight line unless the target changes course. But a missile that pursues a crossing target must follow a curved trajectory (fig. 2-14A). As the missile approaches a crossing target, the target bearing rate increases, and the curvature of the missile path increases correspondingly. In some cases the extreme curvature of the pursuit course may be too sharp for the missile to follow. This results in an unsuccessful missile firing.

COLLISION.–In a collision path, the missile is aimed at such a point ahead of the target that both the missile and the target will reach that point at the same instant. As shown in figure 2-14B, the missile attempts to fly in such a direction, that successive lines of sight will be parallel. (If the missile-to-target los is not changing direction, the missile is flying a collision course. A collision course path is the shortest and quickest path to the target.) Any change in the target's flight path, as shown at point A in figure 2-14C, causes an angular change of the los in space. Any such change is immediately sensed by the seeker (receiver) antenna. This angular change, or rotation, is then utilized to change the missile flight path at point B to compensate for the change in the los. Successive lines of sight will then be parallel to the new los until intercept or until the target again turns.

PROPORTIONAL NAVIGATION.–SMS homing missiles use a method called proportional navigation, which is actually a refinement of a collision path. In order for a missile to maintain a continuous collision course, target maneuvers have to be detected and corrected instantaneously. It is not physically possible to build a system that can react that fast, so a more practical method is needed.

As in a simple collision path, as long as the line of sight does not rotate, the missile is maintained on its straight line path toward collision. If the line of sight begins to rotate, as indicated in figure 2-14C, because of target maneuver or any undesired motion of the missile, the missile flight path control equipment is ordered to turn the missile at a rate that is proportional to the angular rate of change of the missile-to-target line of sight and in the proper direction to reduce the rotation of the line of sight to zero. When the rotation of the line of sight is reduced to zero, the missile is then on its collision course. This is similar to controlling a radar director with a rate signal instead of a position error signal.

LINE OF SIGHT.–Another path that can be flown by missiles is the line-of-sight path. Here, the missile is guided so that it always travels along the line of sight from the launching ship to the target. An example of this is "beam riding", where the missile rides a beam that is radiated from the ship and kept trained on the target. Note that a pursuit path also follows a line of sight, the line of sight from the missile. A beam-riding line-of-sight path follows the line of sight from the launching ship. The beam-rider path (fig. 2-14C) is quite similar to a pursuit path and has the same disadvantages against a crossing or maneuvering target.

SMS MISSILES

Now that you have some general knowledge of missiles, we will discuss some of the missiles you may encounter in the SMS fleet. Although a

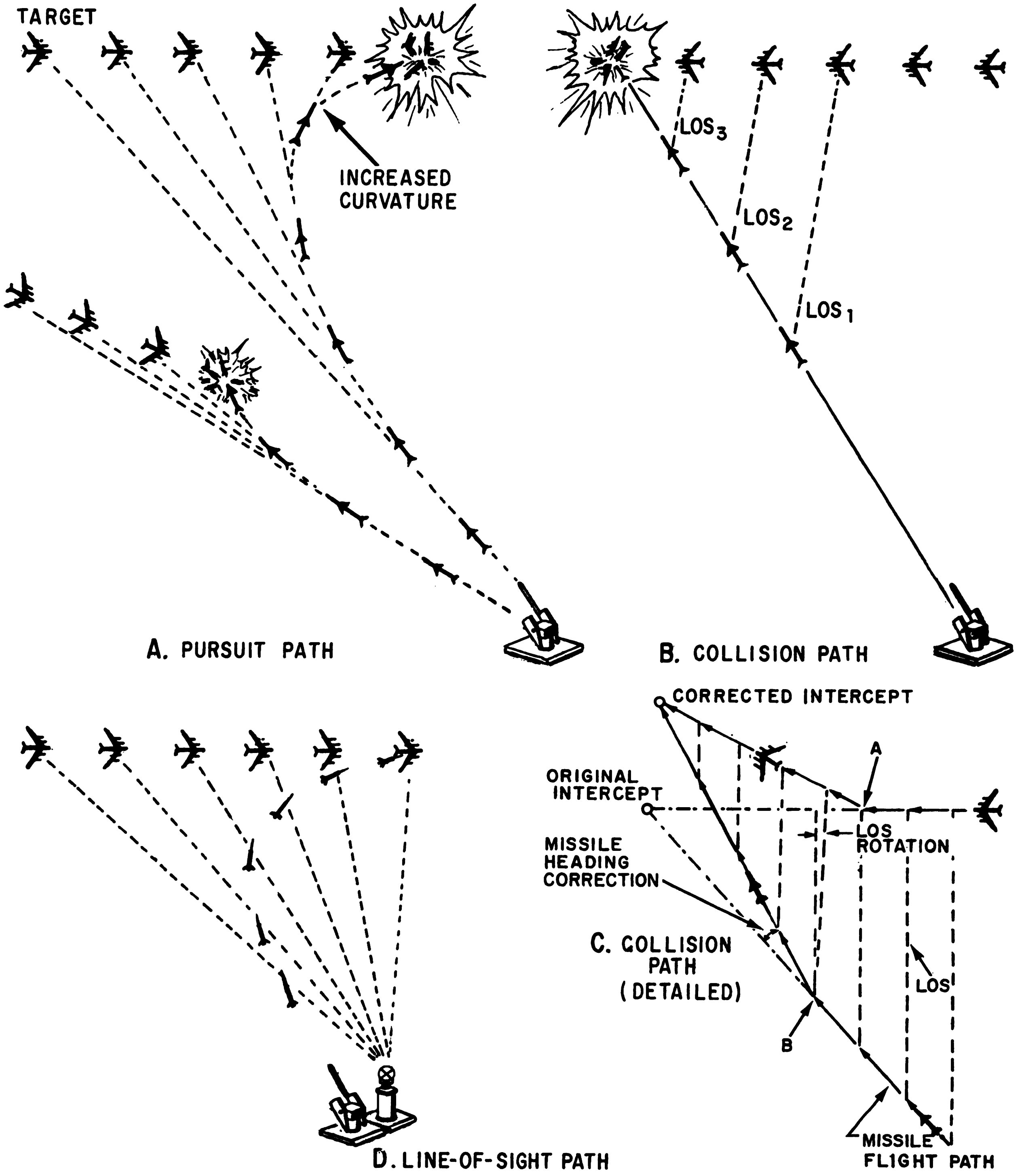

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Figure 2-14.—Types of variable guidance.

few missile configurations are described here, advancement in technology and refinement in design lead to more advanced missiles. Therefore, you may be using some that are not covered in this text.

TARTAR MISSILES

The TARTAR is a short-range homing missile that is rapidly being phased out of operation. The only remaining version is the Improved TARTAR Retrofit (ITR) RIM-24C. This missile is used for exercise firings and will probably continue to be used in this manner until stockpiles are eliminated. It has been replaced by the STANDARD (MR) RIM-66A and RIM-66B missiles, (fig. 2-15). The RIM-66A is also to be phased out. The RIM-66B has a considerably larger rocket motor than did the earlier RIM-24C TARTAR and RIM-66A STANDARD missiles. There is also a STANDARD ARM RIM-66D missile. The RIM-66D, used against ships, is an antiradiation missile that homes on enemy radars and radar installations. It is being phased out in favor of HARPOON. TARTAR and STANDARD (RIM-66 mods) missiles are used on DDGs, FFGs, and CGNs.

TERRIER MISSILES

The TERRIER missile is an extended-range missile. It has a separable booster which provides

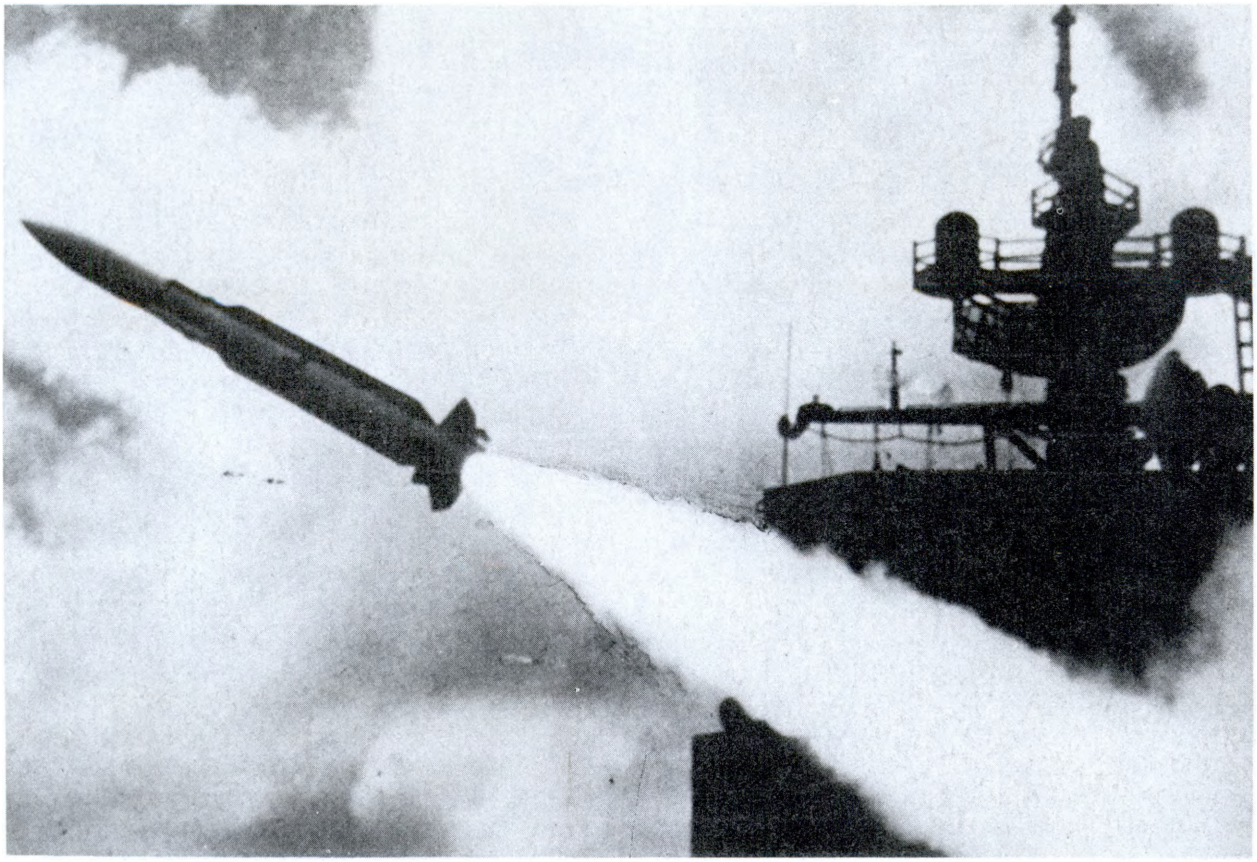

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Figure 2-15.—STANDARD (MR) missile.

greater ranges. One design, RIM-2D, uses beam-riding guidance and is capable of carrying a nuclear warhead. The RIM-2F (HOMING TERRIER RETROFIT) uses homing guidance like the TARTAR missiles. The RIM-2F is being phased out and replaced by the STANDARD (ER) RIM-67A missile (fig. 2-16). Another STANDARD (ER), RIM-67B (SM2-ER) has been developed for TERRIER cruisers. This long-range missile is an adaptation of the SM-2 (MR) missile designed for the AEGIS weapon system. It utilizes midcourse guidance and trajectory shaping to greatly increase its performance envelope.

As with TERRIER missiles, STANDARD (ER) missiles use a booster. TERRIER and STANDARD (RIM-67 mods) missiles are used aboard DDG-37 class destroyers and CG 16 and 28 class cruisers.

SPARROW III MISSILES

The guided missiles for the BASIC POINT DEFENSE (BPD) and the NATO SEA-SPARROW systems is the short-range SPARROW III missile that was designed for air launch from fighter aircraft (AIM-7 series missiles). The mission of the SMS SPARROW III missile (fig. 2-17) is to defend its launching ship (point of origin) from enemy aircraft and guided missiles. In the BASIC POINT DEFENSE system, the missile (AIM-7E) has been modified by the substitution of special wings and tailfins

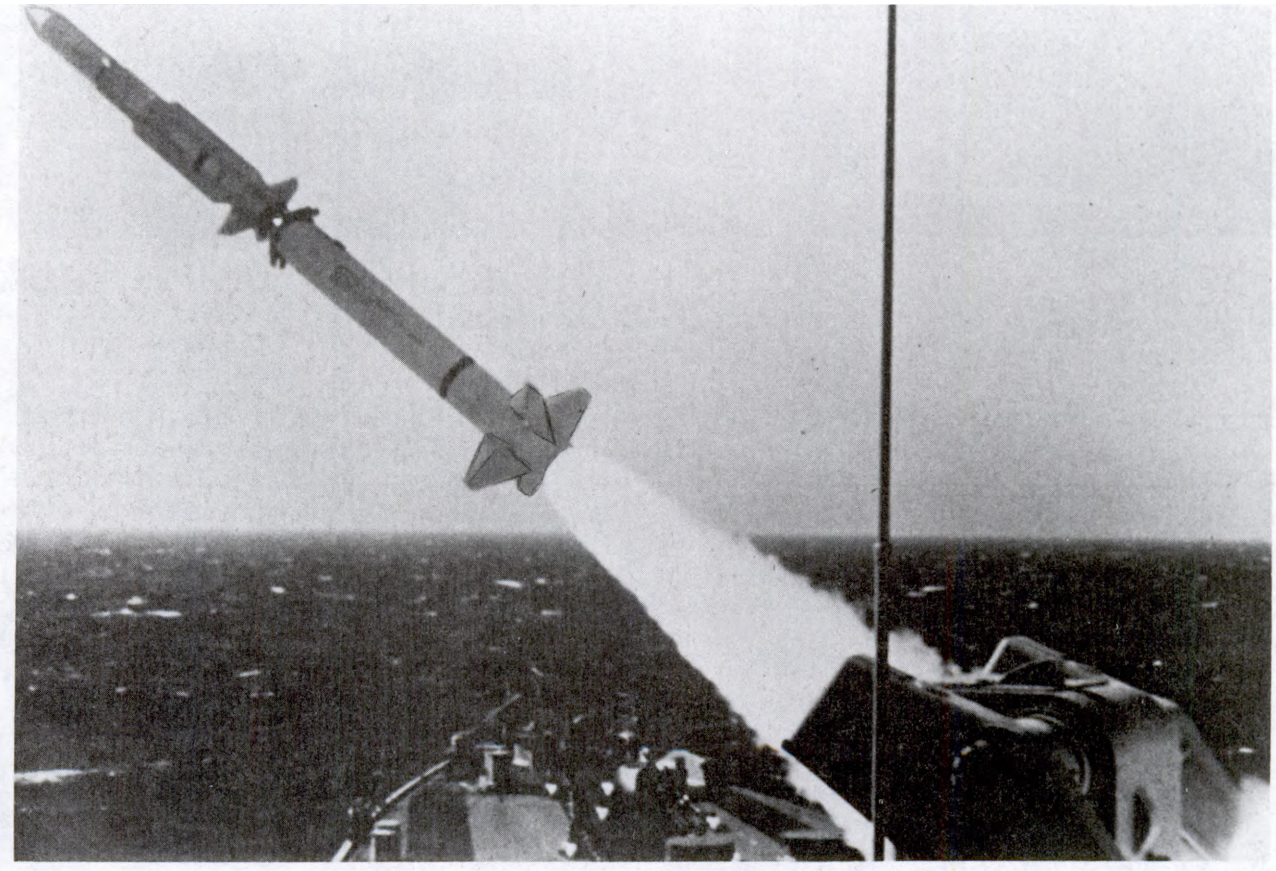

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Figure 2-16.–STANDARD (ER) missile.

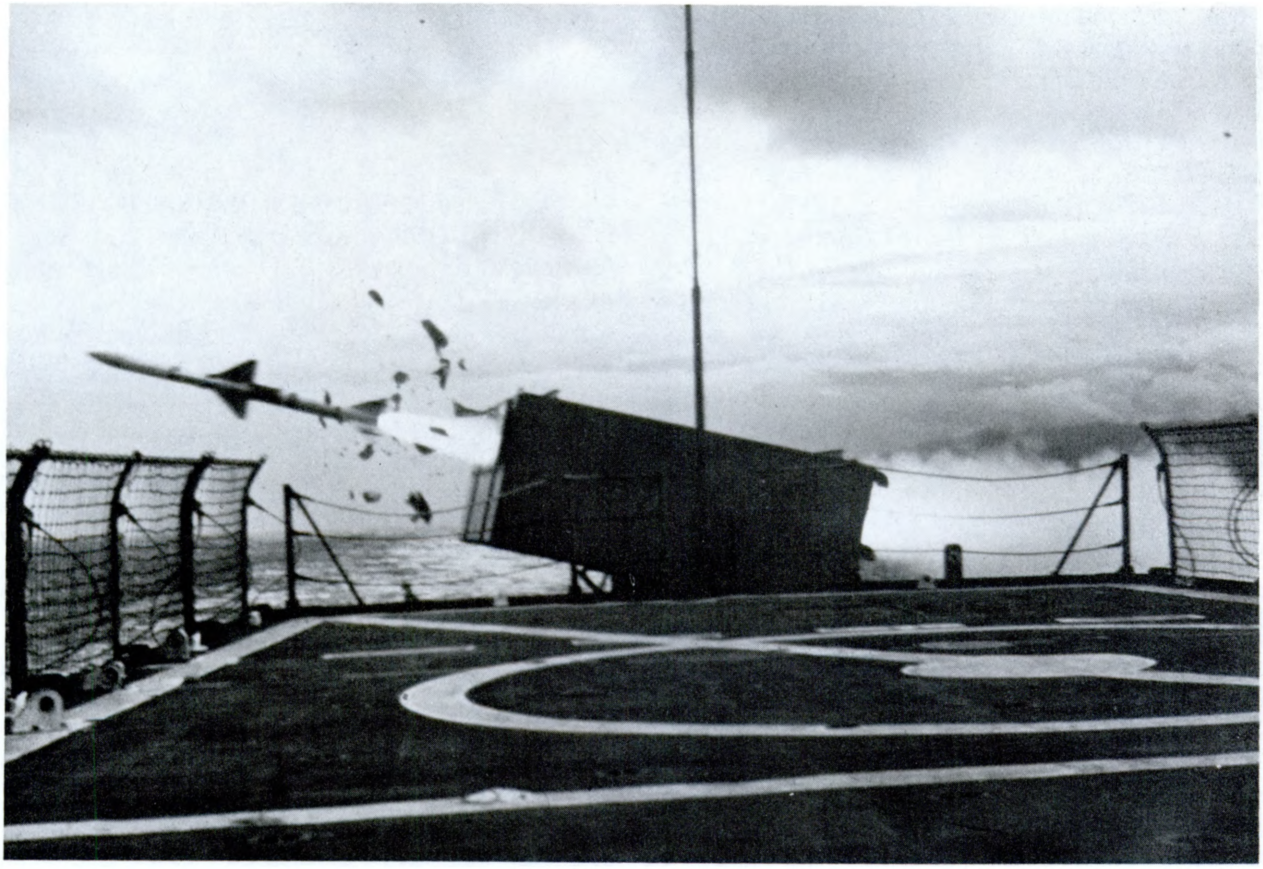

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Figure 2-17.—SPARROW III missile, BASIC POINT DEFENSE.

that have less aerodynamic drag for use at lower altitudes. In the NATO SEASPARROW model (RIM-7H), the missile has been further modified by clipping the fins and making the wings foldable. Because of this, the launcher cells that hold the missiles can be made smaller. This results in an overall reduction in the size of the missile launcher.

HARPOON MISSILES

The HARPOON RGM-84A missile is an advanced all-weather, surface-to-surface guided missile. It can be launched by a number of different classes of surface combatant ships. It is compatible with TARTAR Mk 11 and Mk 13 and ASROC launchers, (fig. 2-18). It can also be launched from a lightweight canister designed for the purpose, (fig. 2-19). The HARPOON missile features over-the-horizon range, a low level cruise flight path (midcourse phase), active homing (terminal phase), and a blast effect warhead. It is propelled at high subsonic speeds by a turbojet engine after a booster-assisted launch.

NEW DEVELOPMENTS

Currently, work is progressing towards introducing new missiles and their associated weapon systems into the fleet. Two of the more

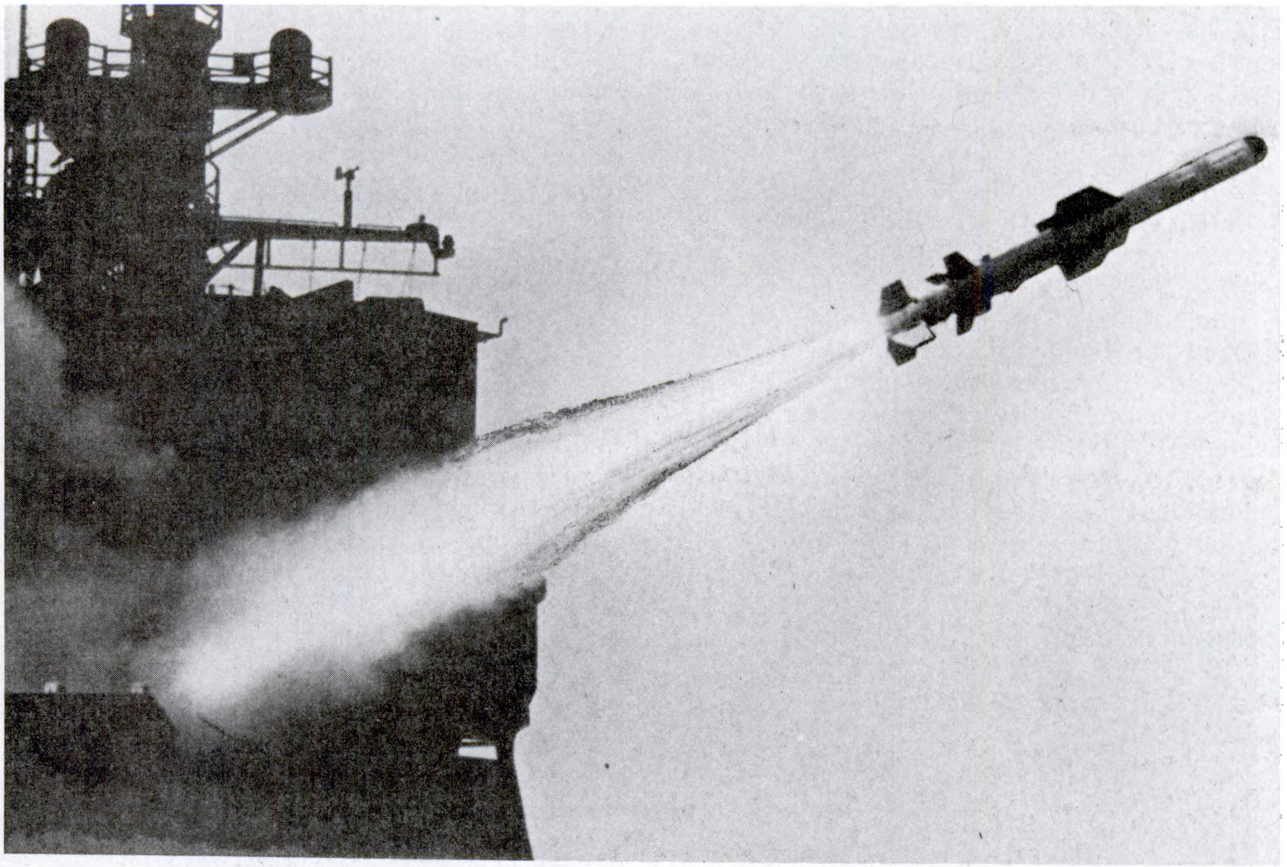

Figure 2-18.–HARPOON missile fired from ASROC launcher. **167.867**

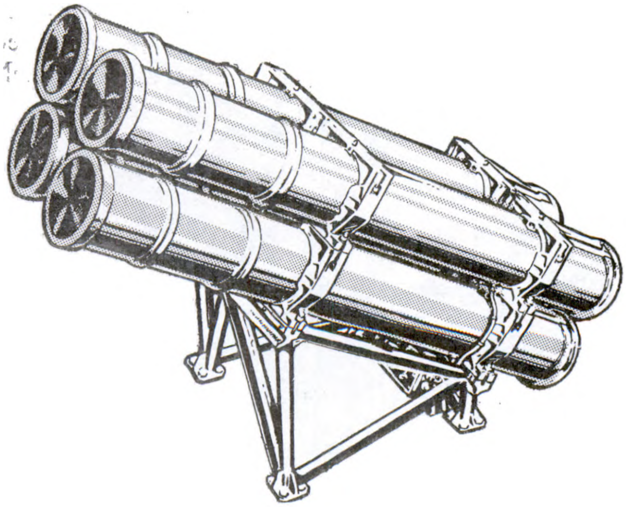

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Figure 2-19.–HARPOON canister launcher.

prominent ones are TOMAHAWK and RAM (Rolling Airframe Missile).

TOMAHAWK

The TOMAHAWK missile can be launched from a variety of air, surface, and subsurface platforms. It is being designed as a long-range cruise missile with both land attack and antiship applications. The range capability of TOMAHAWK, with its high density fuel and turbofan engine, enables it to reach targets which previously could be reached only by ICBMs. The missile's small size, high speed and low-altitude flight path make it virtually immune to enemy defenses.

The TOMAHAWK Land-Attack Missile uses a terrain matching guidance system, carries a nuclear warhead, and has a range of about 3,000 miles. The TOMAHAWK Anti-Ship Missile uses a modified HARPOON guidance system; while its range is only about 350 miles due to the heavier conventional warhead.

ROLLING AIRFRAME MISSILE (RAM)

The Rolling Airframe Guided Missile XRIM-116A, commonly referred to as the RAM missile, is a moderate range surface-to-air self defense missile. The RAM missile uses passive dual-mode (IR/RF) homing guidance. It is proposed to replace the BPDS on fourteen ships (amphibious types) using its own launcher which can store and fire 24 missiles.

Also being developed is a NATO SEA SPARROW/RAM ORDALT which would use the NSSMS launcher with an adapter to place 10 RAM missiles into 2 of the 8 cells of the launcher.

SUMMARY

You have been introduced to the SMS family of guided missiles. The introduction has been of a fundamental nature, covering what a guided missile is, how it is classified, and to a degree, how it is guided, stabilized, and propelled. A typical guided missile is made up of five subsystems—the air frame (structure), propulsion, control, guidance, and warhead. You know how these subsystems are related to each other, insofar as the basic concept of missile operation is concerned. Finally, you know the SMS missiles by name and have some insight as to how and for what purposes they are used.

The next chapter describes the basic concepts of weapon control systems used for the control of guided missiles. The various components of a missile control system, along with a description of their functions, is part of the presentation. Elements of the missile fire control problem are explained by describing a normal missile firing evolution from detection to target kill.

CHAPTER 3

THE WEAPON CONTROL SYSTEM

In chapter 2, you were introduced to the guided missile. As a result of your study, you know what a guided missile is, how it is classified, and how it is guided, stabilized, and propelled. You also have been introduced to the SMS family.

This chapter describes a shipboard weapon control system. (The description is directed toward the guided missile even though the system can be used to control other weapons, such as guns.) The system will be described in terms of the fire control problem, system functions, information gathering techniques, and missile control. Finally, as a summary, the operational phases of a weapon system are described. First we will consider the fire control problem.

FIRE CONTROL PROBLEM

The fire control problem may be stated as follows: How must a missile be fired at a target (stationary or moving) from a ship (stationary or moving) to obtain a hit on the target? In order to accomplish the problem's solution, we must have effective control of our missile. An accurate solution of the missile fire control problem provides us with this control.

The definition of fire control states that fire control is the technique of delivering effective fire so as to damage or destroy a selected target. Since there is one basic fire control problem, it is logical to assume that many fundamental elements (basic quantities or factors) are common to all variations of the problem. Therefore much of the material in this chapter is common to each surface missile system of the Navy. Some of these common elements are:

- A LINE OF SIGHT (los)—An imaginary line from your ship's fire control radar to the target's present position.

- PREDICTION QUANTITIES—Used to locate target and missile future position.

- LINE OF FIRE (lof)—An imaginary line along which the missile is launched.

How these elements of the problem are acquired should become obvious as you proceed through this chapter.

The basic problem can be divided into six fundamental sequential operations: DETECTION, ACQUISITION and TRACKING, PREDICTION, LAUNCHER POSITIONING, GUIDANCE, and EVALUATION (intercept). Figure 3-1 illustrates the fire control problem sequence. The SMS fire control problems include these operations, and are described as follows:

TARGET DATA

The first fundamental and necessary step in the problem's solution is the gathering of all information relative to the problem. One of the most critical pieces of information that must be determined is that a target exists. This requires the use of some form of detection system. This is normally accomplished by a search radar system, which permits detection at extreme distances, in darkness, and during all types of weather. (As you will learn, this function can be performed in other ways, but for now, let us consider only a search radar.)

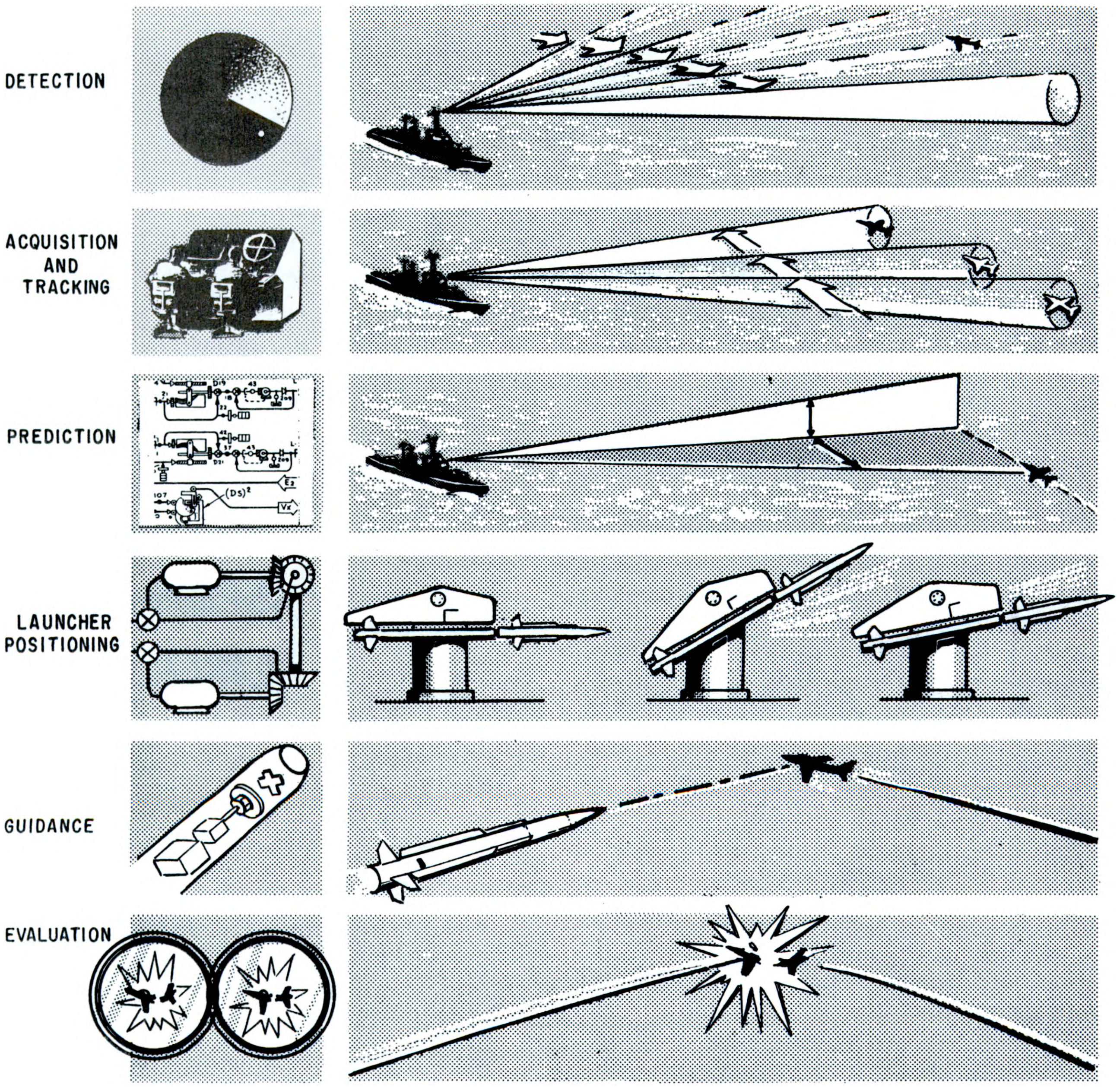

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Figure 3-1.—Fire control problem sequence.

After a target has been detected, the next step is to obtain precise target position information. This information can be provided by the same source that detected the target, or it can be provided from some other source, such as another radar. In the majority of cases, a second radar, referred to as a fire control radar, is used.

The search radar normally detects the target and establishes the target's initial position. The initial target information is transmitted (designated) to the fire control radar.

The fire control radar antenna is then aligned with the search radar's target position information until it locks on the reflected target signal (acquisition), and it is maintained in that alignment (track) while the ship and/or target is moving. In this way, continuous, accurate target position information is available to the weapon system for processing. Not only is the continuous present position of the target obtained, but its movement (course and speed) is also determined.

Ancillary Data

Information other than target data is often equally important for missile flight path (trajectory) determination. Wind, for example could blow the missile off its flight path. Appropriate corrections would require that wind direction and velocity be determined. The course and speed of the launching ship and its motion due to the sea (pitch and roll), are also considerations. If this type of data is not included in the flight path determinations, it could cause large errors in the flight path (trajectory).

Information or data of this nature, along with target information, is transmitted to the fire control system's computer. The computer performs the necessary calculations for computing the launcher position angles and the missile's flight path.

FIRE CONTROL OPERATION

After target detection and target acquisition has occurred, the missile fire control system provides for the tracking, computation (prediction) and positioning functions (fig. 3-2). As a missile fire control technician, these are

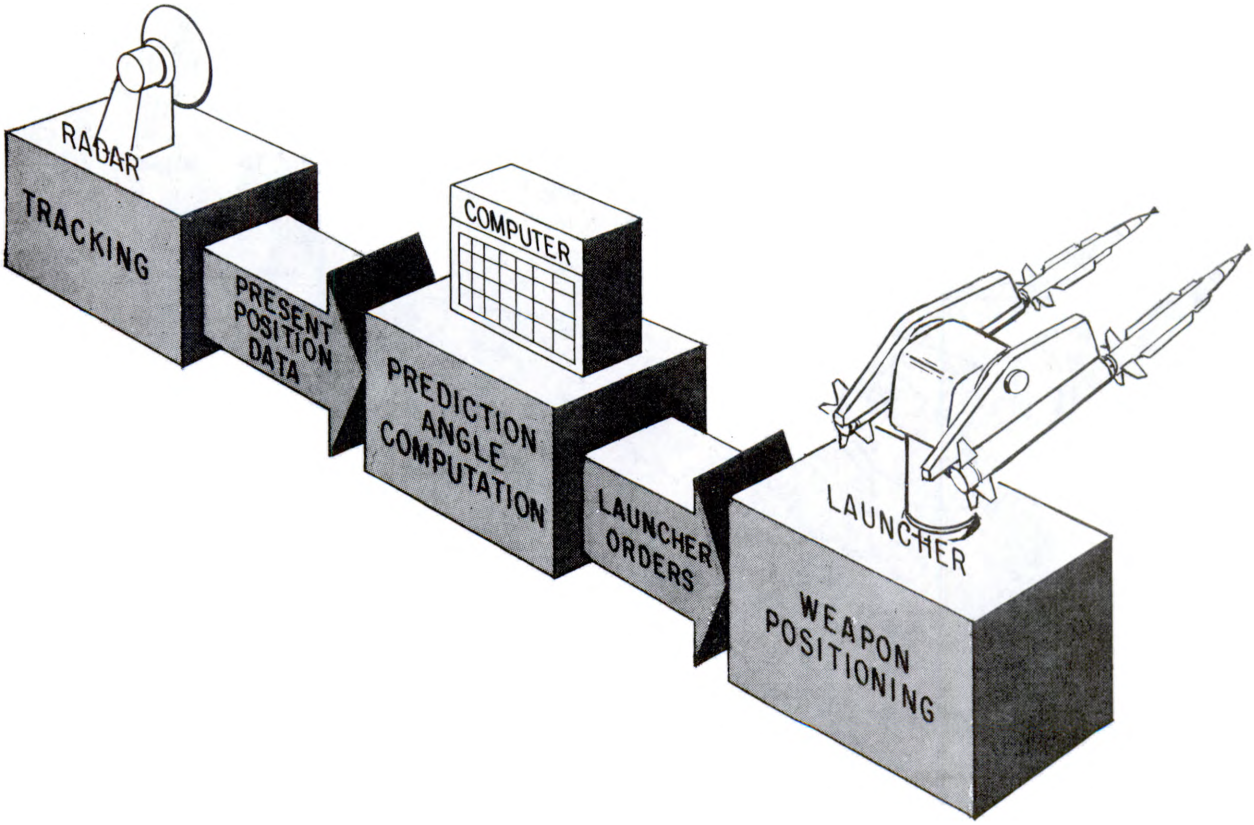

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Figure 3-2.—Fire control operation.

operations with which you will be highly involved.

Tracking

The first operation, performed by the tracking subsystem, tracks the target and provides all necessary data on the target. The fire control radar performs this function by establishing a tracking line of sight (los) along which it receives the returned or reflected energy from the target. It also provides accurate range data.

Since the speed of the propagated rf energy is about 186,000 miles per second (the same as the speed of light), and since the target ranges involved are relatively small, the time for the energy to travel to and from the target can be considered as instantaneous. Therefore, the radar indications of the target can be considered as instantaneous present target positions.

Computation

The second operation of the fire control problem that must be performed is the computation of the missile launcher positioning angle (line of fire) and the guided missile flight path projectory. This operation consists of two parts. First, the data which is received is processed into a usable form, and then the arithmetic operations are performed by the fire control computer.

Launcher Positioning/Missile Guidance

The third operation that must be performed is the positioning of the launcher, in accordance with the calculated line of fire, and missile guidance. This amounts to offsetting the launcher axis from the los by the amount of the predicted lead angle by means of the launcher drive mechanism. In some cases, the missile is positioned (guided) in flight by the fire control system. This is done with a guidance beam in the case of a beam-rider missile. In the case of a command guided missile, the fire control computer sends steering orders via an rf data link.

Surface-to-Air Missile Problem

After the search radar has located the attacking aircraft, the fire control radar tracks the aircraft. The missile is not fired directly at the collision point, but is aimed a little higher (superelevation) in order to compensate for the effects of wind and gravity and to allow the missile to climb to a higher altitude (fig. 3-3). As

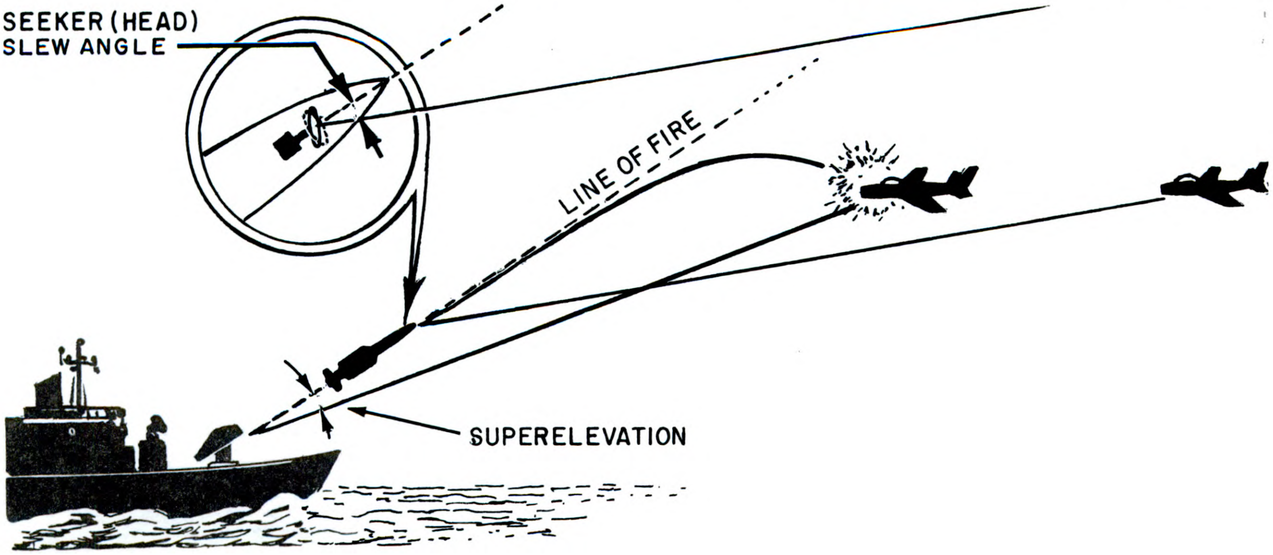

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Figure 3-3.—Simplified fire control problem.

a result, the missile receiver (seeker) antenna is also pointed above the target. Therefore, the missile fire control computer must tell the seeker antenna where to look for the target.

In order to do this correctly, the fire control computer must know where the target will be when the seeker turns (slews) to look for it, as well as where the missile will be at the time. The blow-up in figure 3-3 shows the seeker antenna slewed toward the target.

Once the missile locks on the rf signal reflected from the target, it begins to steer toward a point of intercept.

MISS PRODUCING EFFECTS.–Many factors serve to complicate the fire control problem. Some affect the accuracy of the problem solution. This inaccuracy could hinder the missile from locking on the target. Other factors may have a direct effect on the missile itself. It would be simple if the launching platform and the target were both sitting still in outer space where forces such as gravity, wind, and air resistance would not be factors. But, in reality, the opposite is the case, and where necessary, these effects are compensated for in the fire control computer when they are fairly constant and predictable. Good examples of effects that can be compensated for are gravity and the movement of a launching ship. Wind quantities are also sometimes compensated for.

The missile can be affected by still other factors. For instance, electromagnetic interference (EMI) may occur between two or more fire control/guidance radars. This might cause the missile to home on the wrong target or to miss altogether. The enemy can initiate electronic countermeasures (ECM) that could decrease the missile's chance for a successful intercept. Missile design has included circuitry to minimize or in some cases eliminate all of these effects.

FIRE CONTROL SYMBOLS

The fire control symbol system establishes a uniform pattern for all quantities used in surface, antiaircraft, and underwater fire control problems. This includes gun, missile, and underwater weapons found aboard ship. Symbols are not new to you. Mathematics, electricity, and electronics use them extensively. The need for symbols is obvious. The various problems are expressed in symbols, for they are the language of the fire control technician.

Basic Format

In the present system of fire control symbols, all common features of the problem are divided into certain main classes of quantities, such as bearing, elevation, and range. The basic geometric quantity in each class is represented by a basic symbol (for example, B for bearing, E for elevation, and R for range). In each class, other geometric quantities are expressed by applying modifiers to the basic symbols. These modifiers express the way in which the quantity is measured.

For example, range represents the linear distance between ownship and the target. It is expressed by the basic symbol R and is measured along the line of sight (fig. 3-4). Another quantity in the same class is the linear

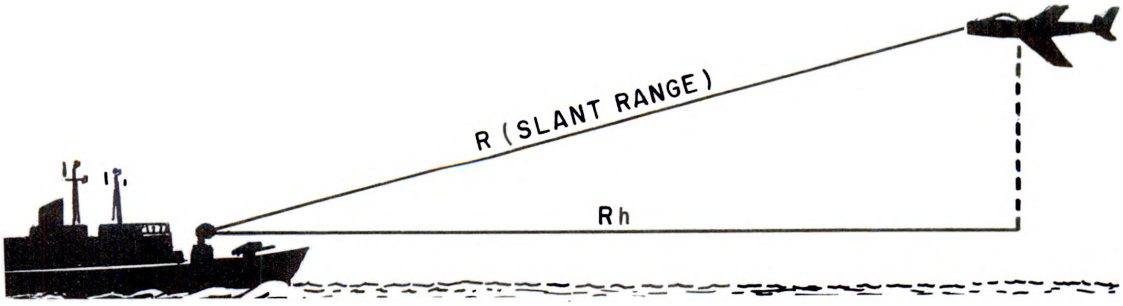

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Figure 3-4.–Geometrical quantities of range.

distance between ownship and the target measured in the horizontal plane. This quantity is symbolized by adding the modifier h (meaning measured in the horizontal plane) to the basic symbol for range. This forms the symbol Rh.

Basic Symbols and Modifiers

The basic symbols assigned to represent the basic geometric quantity in each class, and the letters and numerals used to modify these basic symbols are contained in the following lists:

Basic Symbols	
B	Bearing
C	Course
D	Rate of
E	Elevation
Ei	Level/Pitch
I	Inclination
K	Arbitrary Constant
L	Sight deflection
M	Linear movement
P	Launcher Parallax Displacement
Ps	Director Parallax Displacement
R	Range
T	Time
U	Speed
V	Sight Angle
W	Wind Rate
Z	Cross level/Roll

Modifiers	
b	bearing
c	computed
d	deck
e	elevation
g	gun/launcher
h	horizontal
m	missile
o	ownship
p	prediction
q	heading
r	range
s	line of sight
t	target
v	vertical
w	wind
x	east-west
y	north-south
z	cross-level
1	order
2	future position
3	launching position
4	aiming position
5	fuze
6	capture/slew position
	prime (normal plane)

A few examples of symbol construction should give you a better understanding of how the system works.

Example

D = Rate of
M = Linear Movement
b = bearing
DMb = Rate of linear movement in bearing

Example

B = Bearing

y = North-south

By = True bearing (measured from north-south axis)

Example

R = Range

h = horizontal

x = East-west

Rhx = Horizontal range along an east-west axis.

For a more detailed listing of the basic symbols and basic symbol modifiers, refer to Appendix I at the end of this manual.

Quantity Modifiers

So far, we have only discussed basic symbols and basic symbol modifiers. Modifications to the basic quantity that account for various effects are also symbolized. These quantity modifiers are applied by enclosing the basic symbols in parentheses and putting the quantity modifier before or after the symbol.

In general, when the modifier comes before the parentheses, the new symbol defines a correction to the basic quantity due to the effects of the modifier. If the modifier follows the parentheses, the new symbol defines a basic quantity that has been corrected for the effects of the modifier. For instance, with Mb being linear movement in bearing, w(Mb) is the amount of linear bearing movement due to the effects of wind.

The quantity itself, bearing movement, with a correction for wind is (Mb)w.

The meanings of various letters when used as quantity modifiers of geometric quantities are:

b	ballistics
k	Earth
m	relative motion
p	launcher parallax
ps	director parallax
w	wind

Quantity modifiers may also be used to express the way in which a geometric quantity is obtained. For example, c(B) is computed relative target bearing, d(E) is designated target elevation, e(R) is error in range, and o(mZo1) is observed missile roll order. Quantity modifiers used for this purpose are:

c	computed or generated
d	designated
e	error
1	initial
o	observed or measured
s	selected

For a more detailed listing of quantity modifiers, refer to Appendix I at the end of this manual.

REFERENCE FRAMES

Usually, telling where something is located presents us with no particular problem. From early childhood we have all become accustomed to answering "where" questions, and in ordinary circumstances, we find little difficulty in giving information that is good enough for the purpose.

But there's a big difference between telling Aunt Minnie where to find her cat and giving the kind of position information necessary to pinpoint and destroy an enemy aircraft in the atmosphere. In fire control, the exact definition is of prime importance.

A target's position can be described only by relating it to a known reference point, for position is a relative quantity. We describe a location by measuring its direction and distance from a point known to us. (Try to describe any location, say the director or plotting room, without a known starting or reference point.)

The need for a reference or starting point to describe the target's position is obvious. It can also be seen that a system of measuring the direction and distance from that reference point is needed. The systems of measuring from the reference point are called "coordinate" systems.

The reference point is contained in a frame of reference, a system of lines, angles, and planes within which we can measure a target's present position. Each frame of reference has a point from which all measurements are made. This point is called the reference point or the origin. A baseball field can serve to show what we mean by frame of reference. The playing field is established from home plate by the foul lines. The game takes place within these lines. All measurements are made from home plate, the reference point. The importance of the location of the reference point is apparent, since everything is related to it.

There are three frames of reference used in missile fire control. Each is determined by the method used to establish the reference point. The reference point is normally located within ownship or the missile. The advantage in this location is that all measurements are therefore made with respect to ownship or the missile.

The three frames of reference are coordinate systems rigidly attached to (1) ownship, (2) the Earth, and (3) the missile. A fire control system may use any one of these frames, or possibly a combination of them. The frame being used can be recognized by the reference point's location and how it was established.

The frame of reference RIGIDLY ATTACHED TO OWNSHIP has a reference point which is built into the weapon system. The system is unstabilized. All measurements of the target's present position are made from the reference point located in the deck plane. The

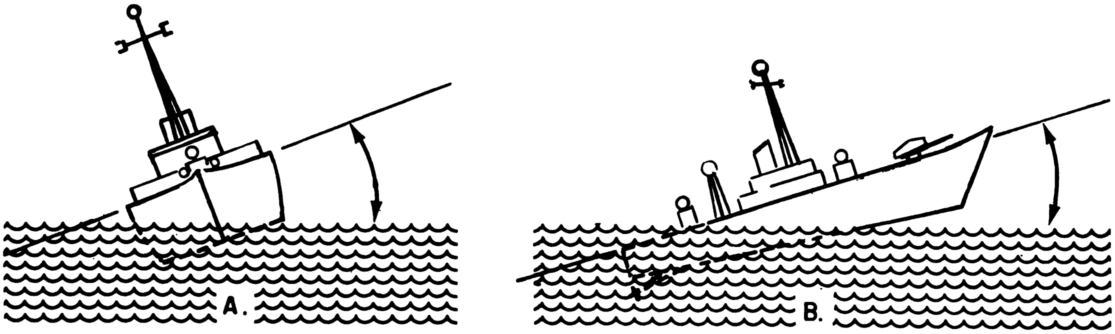

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Figure 3-5.—Deck tilted by A. roll and B. pitch.

deck plane tilts in all directions with the ship as it rolls and pitches (fig. 3-5).

The EARTH frame of reference is considered parallel to the surface of the Earth and rotates with the Earth. The reference point is contained in the horizontal plane, which is stable and independent of the ship's roll and pitch. The horizontal plane is established within ownship or the missile by a gyroscope. The fire control systems using this frame of reference can be either fully or partially stabilized.

In a fully stabilized system all measurements of the target's position are made with respect to the horizontal and vertical planes. The vertical plane is perpendicular (at right angles) to the horizontal plane (fig. 3-6). In a partially stabilized system only a section of the system is stabilized. The stabilized section, normally the computer, measures the target's position with respect to the horizontal and vertical planes. In the other sections of the weapon system (director and missile launcher) the reference

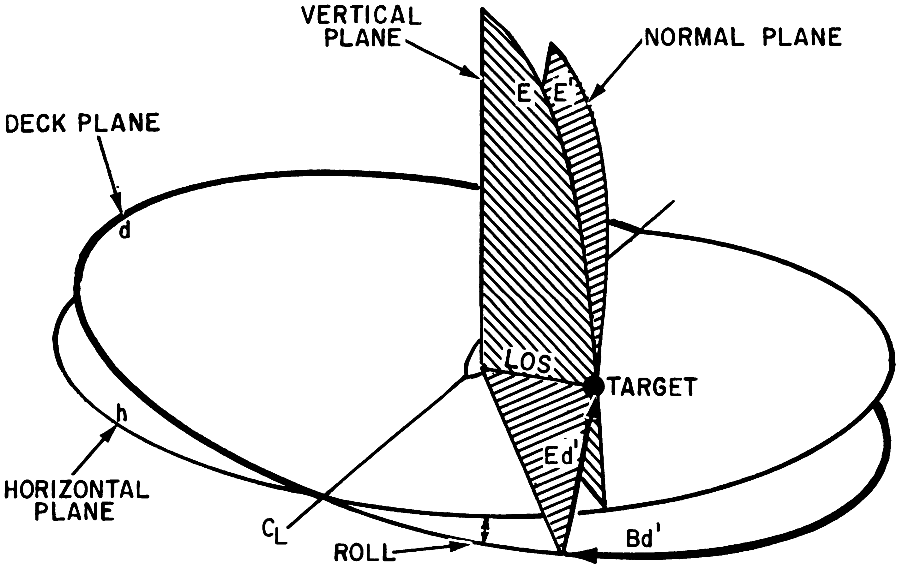

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Figure 3-6.—Reference planes.

point, located in the deck plane, moves with the ship in all directions. Quantities are measured with respect to the deck and normal planes. The normal plane is perpendicular to the deck plane. Most SMS fire control systems are partially stabilized.

The frame of reference RIGIDLY ATTACHED TO THE MISSILE has a reference point built into, and moving with, the missile. The missile's reference planes, containing the reference point, are oriented to ownship's reference planes when the source of guidance is located in ownship. An example would be a beam-rider missile. When the source of guidance is contained in the missile, its reference planes are oriented to the Earth or to an inertial space frame. Missile and torpedo systems, for example, may use this frame of reference.

COORDINATE SYSTEMS

The target's present position is located in a frame of reference by a coordinate system. The coordinate system measures the target's distance and direction from the reference point. A coordinate system gives a graphic representation of the target's present position.

We can define a coordinate here as a number representing the length of a line that has a known direction relative to a reference axis. To locate a point in a plane requires two coordinates. Each coordinate represents a dimension. As an example, ownship's location can be determined by the coordinates of latitude and longitude (fig. 3-7). It would follow then that a surface target's location from ownship can be determined by two dimensions. In this case both ownship and the target are in the same plane.

There are two basic coordinate systems used to locate a point in a plane: (1) the rectangular or Cartesian coordinate system, which uses two linear coordinates; and (2) the polar coordinate system, which uses one angular and one linear coordinate.

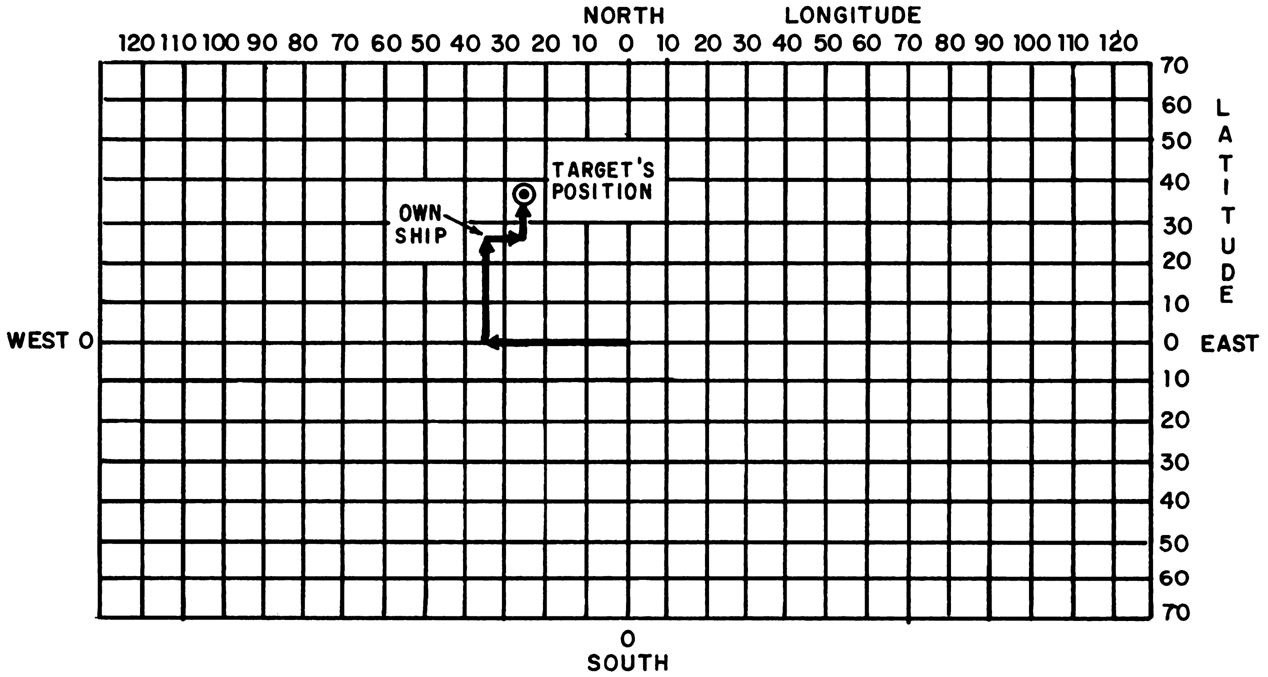

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Figure 3-7.—Earth's coordinates (latitude and longitude).

Rectangular Coordinate System

The rectangular coordinate system uses a frame of reference similar to that shown in figure 3-8. The two lines, X and Y, intersect at right angles. The horizontal line is usually labeled X and called the X axis. The vertical line is usually labeled Y and called the Y axis. The point where the X and Y axes intersect is called the origin, and labeled with the letter O. The origin is, of course, the reference point.

The origin is the starting point for measuring along both axes. To the right of the origin, numbers on the X axis are positive and to the left they are negative. The numbers along the Y axis above the origin are positive; below the origin they are negative.

A point anywhere in the plane of the graph may be located by two numbers. One number shows the distance of the point from the origin along the X axis. The other number shows the distance of the point from the origin along the Y axis. Thus, point P in figure 3-8 is six units to the right of the origin along the X axis and three units above the origin along the Y axis. When the coordinates are written, the X coordinate is always written first. The coordinates for point P would be written: P(6,3).

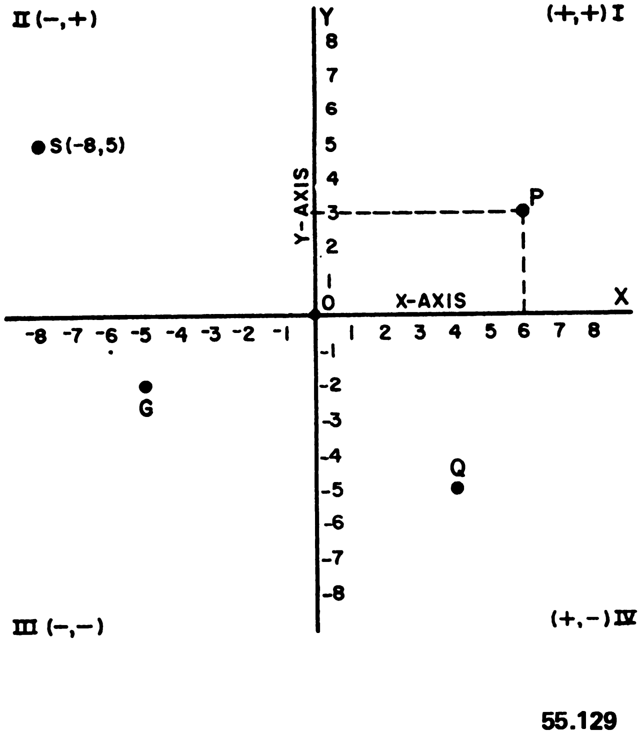

Figure 3-8.—Rectangular coordinate system.

QUADRANTS.—The X and Y axes divide the graph into four parts called quadrants. In figure 3-8, point P is in the first quadrant; point S is in the second quadrant; point G is in the third quadrant; and point Q is in the fourth quadrant. In the first and fourth quadrants, the X coordinate is positive, because it is to the right of the origin. In the second and third quadrants, the X coordinate is negative, because it is to the left of the origin. The Y coordinate is positive in the first and second quadrants, being above the origin, and negative in the third and fourth quadrants, being below the origin. The signs of the coordinates in the quadrants are shown in the figure.

Locating points with respect to axes is called "plotting the points." As shown with point P (fig. 3-8), plotting a point is equivalent to completing a rectangle. This is the reason for the name rectangular coordinate system.

Polar Coordinate System

The polar coordinate system is developed on a frame of reference similar to the rectangular coordinate system. The two lines, X and Y (fig. 3-9), intersect at right angles. The origin, labeled with the letter O, is at the point of intersection. The origin is the axis, or pole, around which the angular coordinate revolves.

A point anywhere in the plane of the graph can be located with two coordinates. The linear coordinate is the distance of the point from the origin. This distance is called the radius and is usually symbolized by the letter r. Since r denotes distance (range) and not direction, it is always positive.

In many mathematical computations, the angular coordinate is measured from the X axis to the right of the origin. The angle increases as it is rotated counterclockwise. In fire control applications, however, we measure bearing angles from the Y axis. Also, the angle increases as it is rotated in a clockwise direction. This is done for convenience, and, conventionally, bearing is measured clockwise. The principles of the polar coordinate system remain the same.

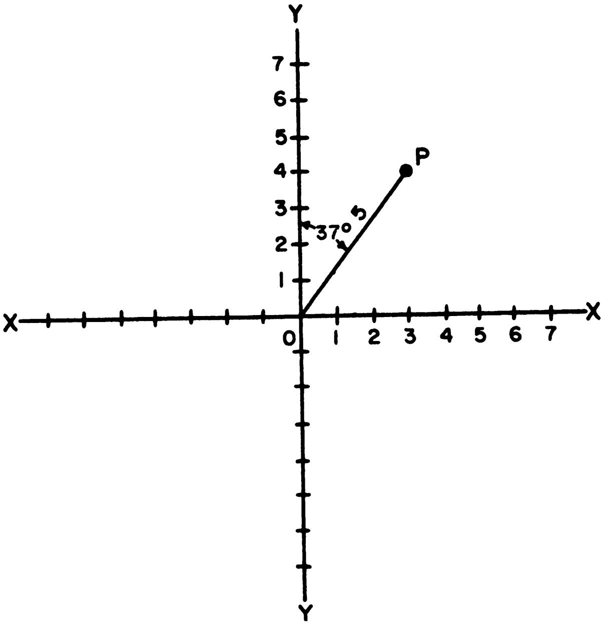

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Figure 3-9.—Polar coordinate system.

We simply have reversed the direction of rotation and shifted the axis 90°.

In describing the location of a point, the coordinates are placed within parentheses. The linear value is always written first. The coordinates of point P (fig. 3-9) are written: P(5,37°). Thus, point P is five units from the origin along a line that forms an angle of 37° with the Y axis.

Three-Dimensional Coordinate System

Until now, we have assumed the target would be in the same plane as ownship. If a target is not on the surface of the Earth, three dimensions are required to describe its position.

To locate a point not in the reference plane, the point's deviation from the reference plane must be described. The deviation is its height measured from the reference plane. The deviation can be described by either an angular (elevation) or linear (altitude) value.

When the angle of elevation is used (fig. 3-10), the angle is measured at the origin. One side of the elevation angle is in the reference plane. The other side, the line R, connecting the origin with the target, is in a slant plane.

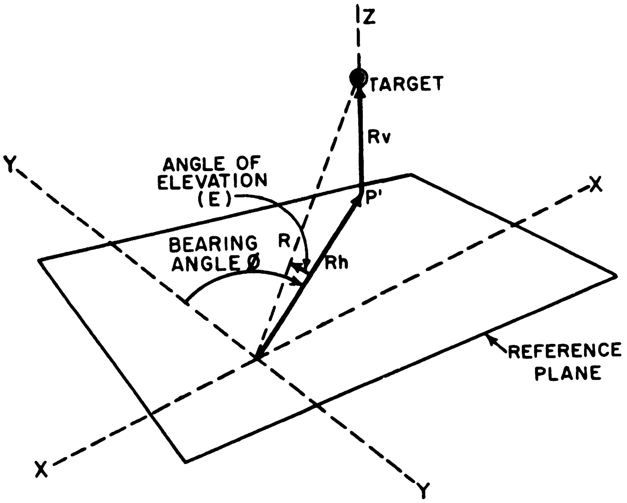

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Figure 3-10.—Three-dimensional polar coordinate system.

The line, Rv, establishes point P in the reference plane. Rv is constructed perpendicular to the reference plane; thus, point P is directly beneath the target. The polar coordinate, Rh, and the bearing angle, Ø, describe the position of point P in the reference plane. The third coordinate, describing the target's position with respect to the reference plane, is the measured angle of the target's elevation, E.

The linear value of the target's altitude, Rv, can be computed from the right triangle—R, Rh, Rv—in figure 3-10. The range of the target from the origin and the angle of elevation are measured. The linear value of Rv can be found by the formula

$$Rv = \sin E \times R$$

The distance from the origin to point P in the reference plane can be found by the formula

$$Rh = \cos E \times R$$

The position of the target in figure 3-11 can be described by three coordinates. We first establish point P in the reference plane, directly beneath the target. The position of point P can be described by the rectangular coordinates Rhx and Rhy. The altitude, Rv, is the third coordinate used to describe target's position. The altitude is measured along an axis perpendicular to the reference plane. This axis is usually labeled with the letter Z, and called the Z axis.

TRANSMISSION OF COORDINATES

Normally, targets are detected by the ship's search radar. The target's position information is then transmitted to the fire control system by a coordinate system. Frequently the coordinate system used by the search radar must be converted to the one used by the fire control system.

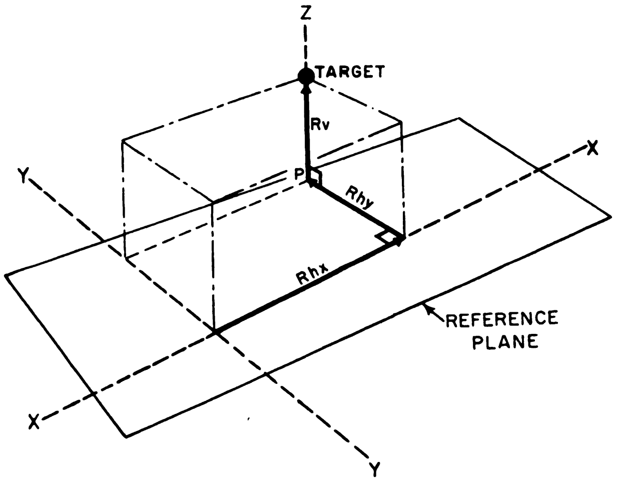
Coordinate Conversion

The coordinate system serves merely as a convenient device to describe the location of a target. The location of a target does not change when a different coordinate system is used to describe it. In figure 3-12 we have located a point in each quadrant. Both rectangular and polar coordinates are given for each point's location. This is possible since both systems have the same frame of reference. When a point is plotted by one coordinate system, the other coordinate system's coordinates may be measured. This is a graphic method of conversion. There are formulas that convert coordinates, but they are not discussed here.

Translation of Axes

A coordinate system provides the information describing the target's position in a form that can easily be transmitted. As you know, the coordinates are measured with respect to a reference point. When the station receiving the target's position information has its own reference point, the relationship between the two reference points must be established. If the distance between the reference points is measured by linear values, it is called translation of axes. Translation of axes is shown in figure 3-13.

In the example shown, the origin, O, is 3 units to the right along the X′ axis and 4 units along the Y′ axis above the origin O′. Therefore, the coordinates of O with respect to the origin O′, are (3,4). The location of the target, with



55.132
Figure 3-11.—Three-dimensional rectangular coordinate system.

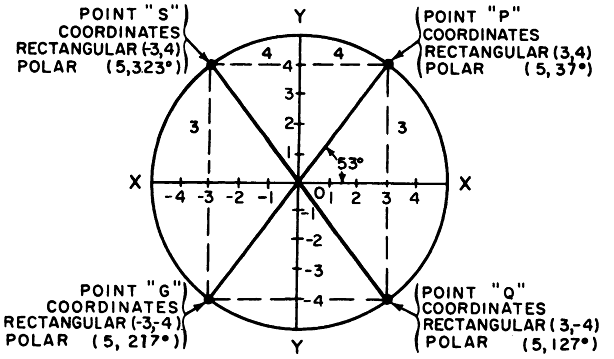


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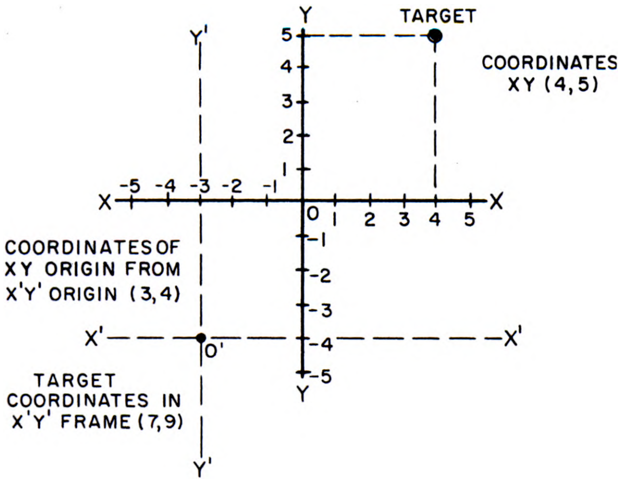
Figure 3-12.—Location of points by rectangular and polar coordinate systems.


Y
TARGET
Y'
COORDINATES XY (4,5)
5
4
3
2
1
-5 -4 -3 -2 -1
X
0 1 2 3 4 5
X
-1
-2
-3
-4
-5
COORDINATES OF XY ORIGIN FROM X'Y' ORIGIN (3,4)
X'
O'
X'
TARGET COORDINATES IN X'Y' FRAME (7,9)
Y
Y'

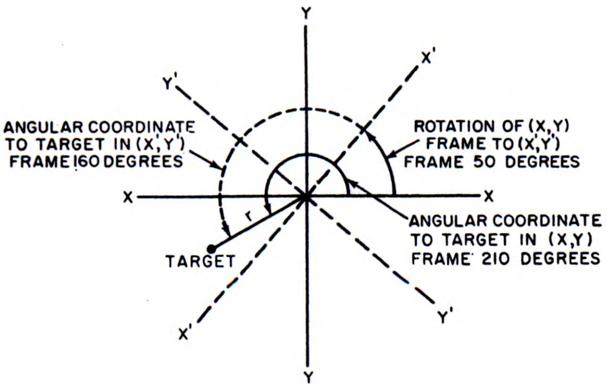
55.134

Figure 3-13.—Translation of axes.

respect to the O origin, is established by the coordinates (4,5). The location of the target, with respect to the O′ origin, is the summation of the coordinates between the origins and the target's coordinates with respect to the O origin. In this example, the target's coordinates, with respect to the O′ origin, are (7,9).

Rotation of Axes

When the frame of reference is transformed angularly, as shown in figure 3-14, it is called rotation of axes. The axes rotate about the origin. Therefore, the range to the target represented by the radial (r) remains constant. The target's angular coordinates from the rotated axes (X′, Y′) is the summation of the angular coordinates from the X and Y axes and the amount of rotation of the axes. When both translation and rotation are performed, a combination of both procedures is necessary.


Y
Y'
X'
ANGULAR COORDINATE TO TARGET IN (X,Y) FRAME 160 DEGREES
ROTATION OF (X,Y) FRAME TO (X,Y) FRAME 50 DEGREES
X
X
r
ANGULAR COORDINATE TO TARGET IN (X,Y) FRAME 210 DEGREES
TARGET
X'
Y'
Y

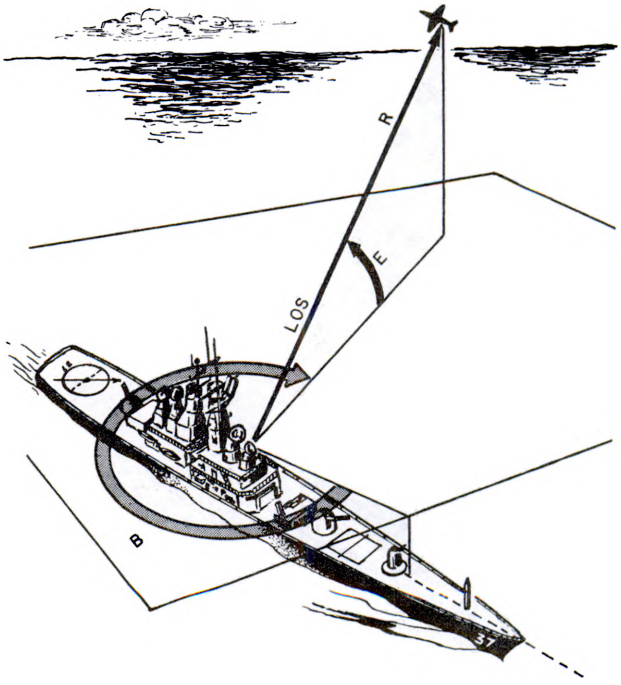
55.135

Figure 3-14.—Rotation of axes.

FIRE CONTROL COORDINATE SYSTEMS

There are many variations of the polar and rectangular coordinate systems. The type of coordinate system used depends on the information available and the ease of mechanizing that information. In fire control, two types of polar and one type of rectangular coordinate system are employed.

The SPHERICAL coordinate system (fig. 3-15) is a polar coordinate system. The ship is in the center of an imaginary sphere, whose radius



55.136

Figure 3-15.—Target position in spherical coordinates.

is equal to the slant range. The coordinates used to express the target's position are:

1. Bearing angle, B, measured from ownship's centerline

2. Elevation angle, E, measured from the reference plane

3. Range, R, measured along the line of sight

The CYLINDRICAL coordinate system (fig. 3-16) is also a polar coordinate system. The ship is in the center of an imaginary cylinder whose radius is equal to horizontal range. The height of the cylinder is equal to vertical range. The coordinates used to express target's position are:

1. Bearing angle, B, measured from ownship's centerline

2. Horizontal (or deck) range component, Rh, measured in the reference plane

3. Vertical (or normal) range component, Rv, measured perpendicular to the reference plane

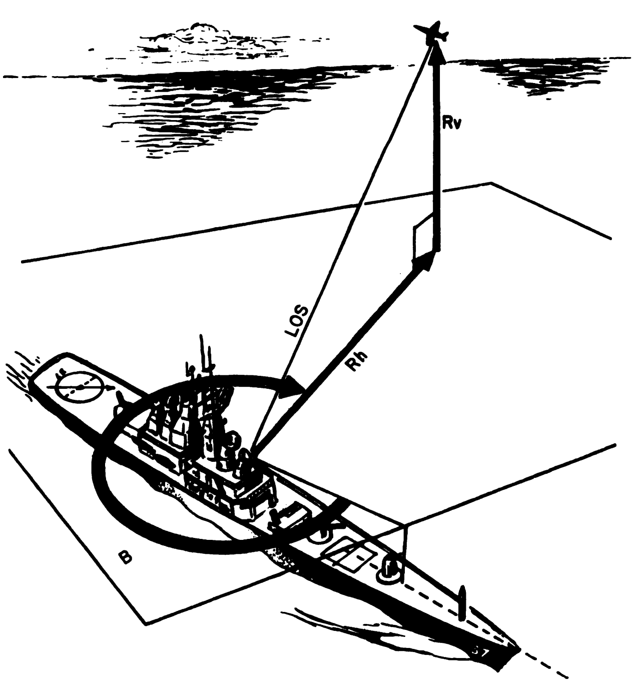
The CARTESIAN coordinate system (fig. 3-17) is a rectangular coordinate system. The quantities used to express the target's position are:

1. Horizontal range component in the east-west axis, Rhx

2. Horizontal range component in the north-south axis, Rhy

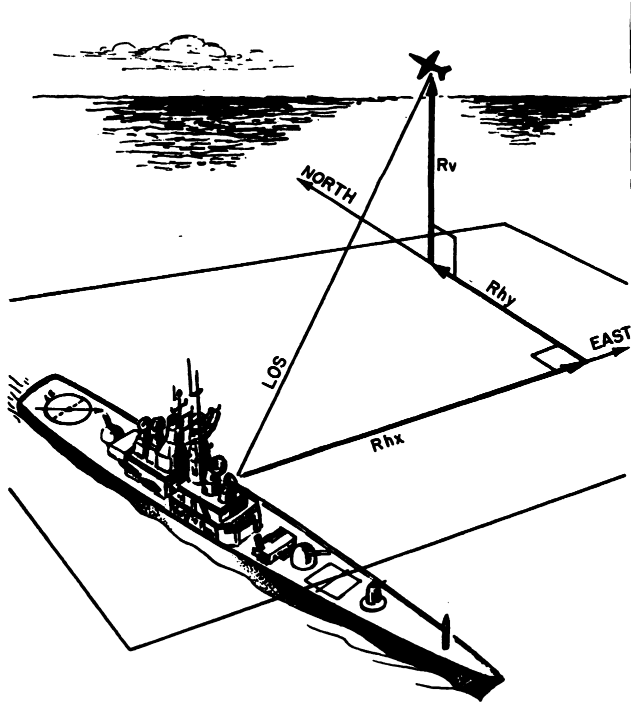
3. Vertical range component, Rv, measured perpendicular to the reference plane

In each coordinate system the geometrical quantities of range, bearing, and elevation describe the target's position. Any one of the three coordinate systems can be used with any one of the four frames of reference. In all cases



55.137

Figure 3-16.—Target position in cylindrical coordinates.



55.138

Figure 3-17.—Target position in Cartesian coordinates.

the reference point is contained within ownship or the guided missile.

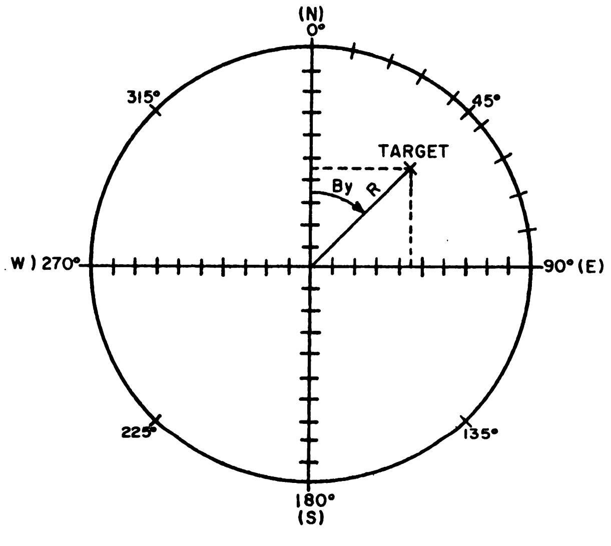
Detection/Designation Coordinates

In a typical weapon system, the primary source of information is the 3-D search radar. Since most of the radars rotate, the logical way to display the radar's information is with a rotating type of indicator, such as a plan position indicator (ppi).

Figure 3-18 shows how true bearing and slant range can be determined on a ppi. True bearing is determined by marking target position relative to the bearing marks around the indicator (scope) face. Slant range is arrived at by measuring the distance the target is from the point of origin (the point where the north-south axis and the east-west axis intersect). These determinations can be made by visual or electronic means. Notice that the ppi has markers relative to true north. The search radar's position, referenced to ownship's centerline, is relative bearing, B. But through rotation of the bearing data's axis, using an input of ships heading, Cqo, from the ship's gyro, the operator sees true bearing, By, information. The quantity, By, is obtained by adding B and Cqo. (If the sum is above 360°, subtract 360 from the sum.)

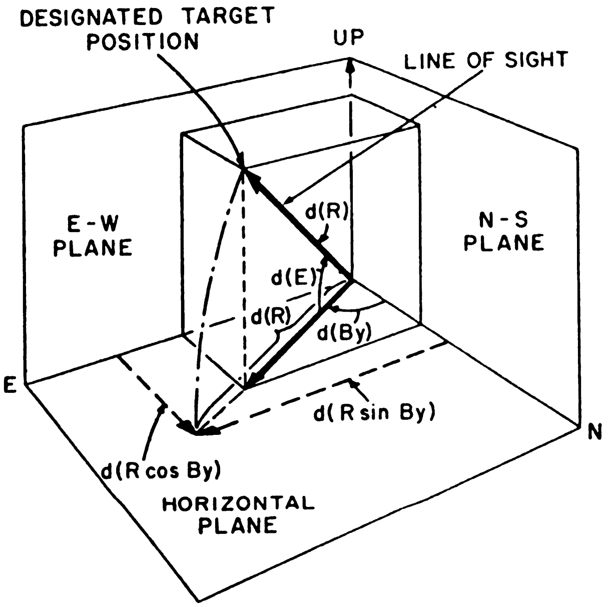
The quantities By and R are not usually sent to the fire control system. The equipment electronics is more suited for handling rectangular quantities. The data, representing target position, is transmitted or designated to the fire control system as d(RsinBy) and d(RcosBy), which are east-west and north-south slant ranges, respectively. Figure 3-19 is a graphic presentation of the slant range quantities. As you can see, these are similar to the Cartesian (rectangular) quantities of Rhx and Rhy, but are in the slant plane. For ease of illustration, the slant range quantities are dropped to the horizontal plane.

The remaining quantity required to locate an object in space can be expressed either as an angle of elevation or as an altitude (height). If one is known, the other can be calculated. In most instances, a 3-D search radar provides a height indication. Target height and slant range



167.8

Figure 3-18.—A ppi representation of By and R.



167.551

Figure 3-19.—Designation coordinates.

can be used to compute the angle of elevation (fig. 3-20). The resultant quantity is sent to the fire control system as designated elevation, d(E).

Acquisition/Track Coordinates

The fire control director sends its information on target position to the computer in the form of bearing, Bd′, and elevation, Ed′ (fig. 3-6). These are spherical polar coordinates referenced to the deck and normal planes. Signals often sent from the computer to drive the director are traverse, DBsd, and elevation, DE′, rates. These are measured in the slant plane and normal plane, respectively.

FUNCTIONS OF THE SYSTEM

A weapon control system is the nerve center of a complete weapon system. It has as its main purpose the control of guided missiles to ensure the maximum kill probability of the weapon system. The various functions of the control system may be categorized as (1) to receive and assimilate information from radar equipment regarding the location, velocity, course, and threat of a target, or targets; (2) to calculate or compute the predicted line of fire so that the missile is launched in the proper direction; (3) to position the missile launcher in accordance with its computed launcher orders; and (4) to control the guided missile flight path to ensure target intercept.

DATA GATHERING

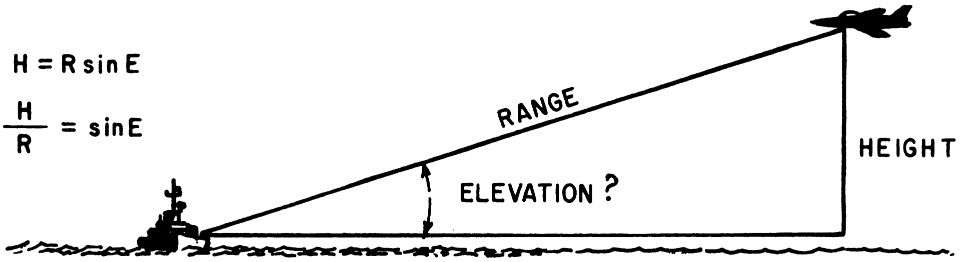
The gathering of data for use as input to the fire control prediction unit of the computer is called DATA GATHERING and is one of the prime functions of a weapon control system. The data must contain sufficient information to allow the computer unit to do more than make an educated guess in its determination of a predicted launch angle.

DATA PROCESSING

Once required data is gathered, it then becomes necessary to compute the predicted launch angle within a predetermined length of time so that the missile may be launched in the proper direction. The intent is to ensure target lock-on by the missile or guidance beam capture of the missile. Computation of the predicted launch angle is a basic requirement of data processing, a second prime function of a weapon control system.

Coordinate Conversion

During the operations of data gathering and data processing, it may be necessary to convert data from one reference frame to another or from a particular coordinate system within a reference frame to a second coordinate system. For instance, target data obtained during tracking is measured in the deck plane.



167.882

Figure 3-20.—Solving for elevation angle.

Environmental data obtained may be measured in the horizontal plane. When the computation accomplished by the computer is in the horizontal plane, the target data must undergo a process of conversion so that it becomes equivalent to data measured in the horizontal plane.

When the target data is measured in spherical (polar) coordinates, but the computation is determined by rectangular (Cartesian) coordinates, then the spherical coordinate data must be transformed into rectangular coordinate data within the stabilized horizontal frame so that the computer may operate properly. At times, the conversions may be in the opposite direction (rectangular to spherical), or they may involve other types of coordinate systems or reference frames. Regardless, these processes are called COORDINATE CONVERSIONS.

LAUNCHER POSITIONING

The fire control computer produces the predicted launch angle as one of its solutions. What remains is for the launcher to be positioned to that point. In order for this to be accomplished, orders must be sent to the launcher directing it to a position coincident to the computed missile line of fire (launch) position. However, it must be remembered that the reference plane of the launcher may not be the same as the one utilized at the computer. For example, a guided missile launcher on a cruiser is referenced in the deck plane. Launcher orders from the computer must then take into account pitch and roll. In other words, a conversion process which compensates for the moving deck reference plane keeps the launcher aimed at a fixed point in space.

MISSILE CONTROL

The methods and the extent to which missiles are controlled vary somewhat from missile to missile. In general, the control is accomplished by the selection of a particular missile type and by missile orders. When the fire control computer is provided with indications of a "missile type selected," it can generate appropriate launcher orders for the missile selected. Missile orders, which affect the missile's flight, are usually supplied while the missile is on the launcher. They can, however, be supplied during flight, as in the case of command guidance.

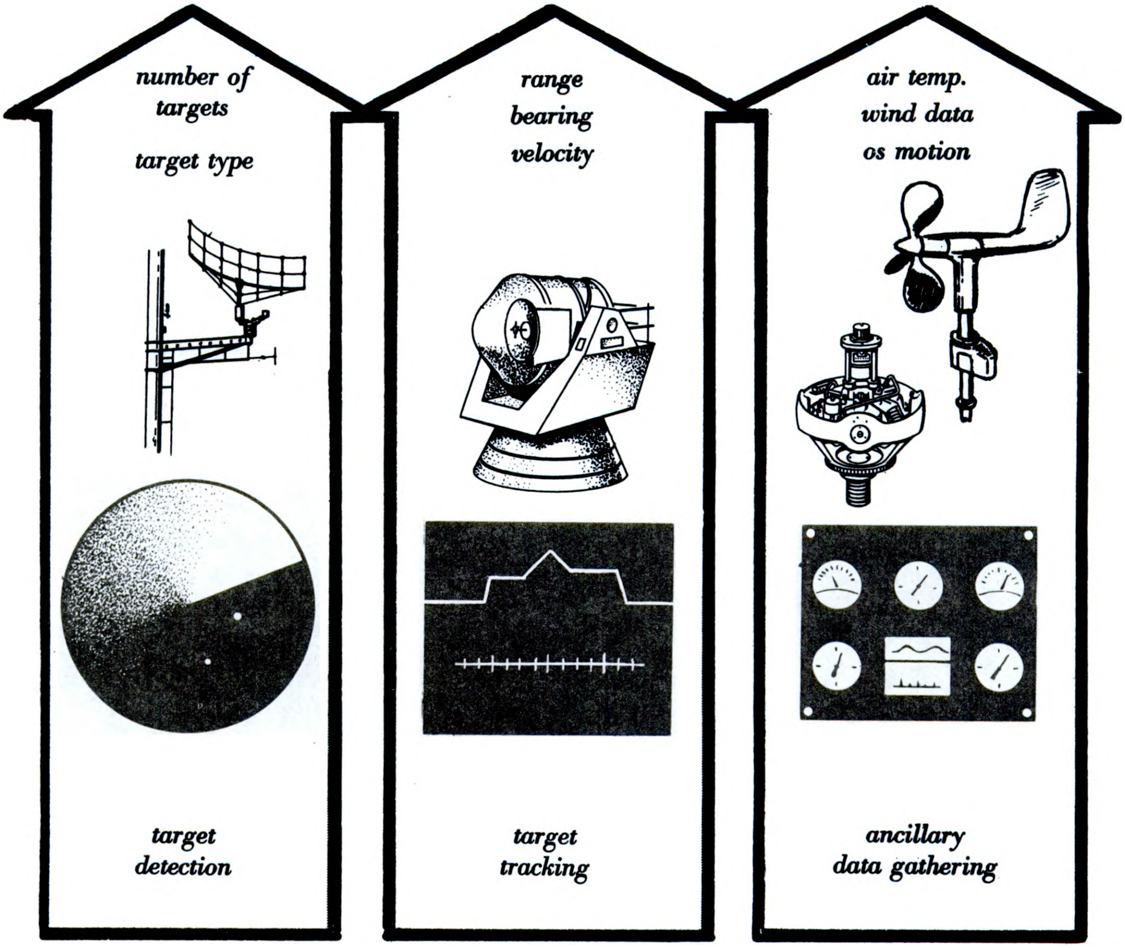
INFORMATION GATHERING

In fire control problems, we are required to find out first that a target does exist. Information is needed on the target, its characteristics, and the threat it poses so that a decision can be made as to which weapon system should be used to destroy the target. When a weapon system begins its task, it requires the location of the present line of sight. It must be supplied also with sufficient information on the target and ownship to determine the launcher positioning angle and missile flight path (trajectory) information. Information gathering procedures are subdivided into target detection, target tracking, and methods of collecting ancillary data (fig. 3-21).

DETECTION

The operation of the detection system initially provides information on target position, type, and quantity. The effectiveness of this data is determined by the individual capabilities of the equipment used. The equipment may be a search radar, the Naval Tactical Data System (NTDS), electronic warfare support measures (ESM) equipment, a fire control radar, or optical devices. The first three equipments, while not actually parts of the missile system, are valuable sources of information for the weapon system.

Before we discuss some of the shipboard equipment, though, let us look at the "AN"



167.713

Figure 3-21.—Information gathering.

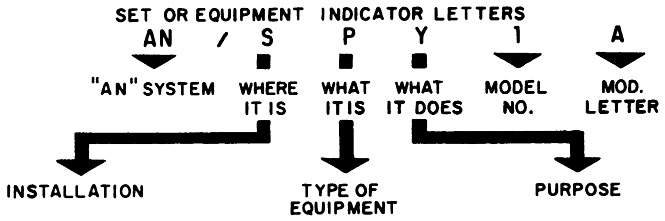
nomenclature system (fig. 3-22). This system was designed so that a common designation could be used for Army, Navy, and Air Force equipment. The system indicator, AN, does not mean that the Army, Navy and Air Force all use the equipment, but means that the classification was assigned using the AN system.

Search Radars

A variety of search radar equipment, with which you may be involved as an FTM, is illustrated in fig. 3-23.

Three-Coordinate Radars

A three-coordinate radar (such as the AN/SPS-39, AN-SPS-48, or AN-SPS-52) is normally the primary source of air target information for a weapon system. These radars provide precise air search data, consisting of range, bearing, and elevation angle, to the Naval Tactical Data System and/or weapon direction system. These radars also provide IFF data. IFF is an electronic system which provides positive identification of friendly targets. The air search data and synchronized identification friend or foe (IFF) interrogation information are displayed on operator consoles in the Weapon



A--AIRBORNE (INSTALLED AND OPERATED IN AIRCRAFT).
B--UNDERWATER MOBILE, SUBMARINE.
C--AIR TRANSPORTABLE (INACTIVATED, DO NOT USE).
D--PILOTLESS CARRIER.
F--FIXED.
G--GROUND, GENERAL GROUND USE (INCLUDES TWO OR MORE GROUND-TYPE INSTALLATIONS).
K--AMPHIBIOUS.
M--GROUND, MOBILE (INSTALLED AS OPERATING UNIT IN A VEHICLE WHICH HAS NO FUNCTION OTHER THAN TRANSPORTING THE EQUIPMENT).
P--PACK OR PORTABLE (ANIMAL OR MAN).
S--WATER SURFACE CRAFT.
T--GROUND, TRANSPORTABLE.
U--GENERAL UTILITY (INCLUDES TWO OR MORE GENERAL INSTALLATION CLASSES, AIRBORNE, SHIPBOARD, AND GROUND).
V--GROUND, VEHICULAR (INSTALLED IN VEHICLE DESIGNED FOR FUNCTIONS OTHER THAN CARRYING ELECTRONIC EQUIPMENT, ETC., SUCH AS TANKS).
W--WATER SURFACE AND UNDERWATER.

A--INVISIBLE LIGHT, HEAT RADIATION.
B--PIGEON.
C--CARRIER.
D--RADIAC.
E--NUPAC.
F--PHOTOGRAPHIC.[1]
G--TELEGRAPH OR TELETYPE.
I--INTERPHONE AND PUBLIC ADDRESS.
J--ELECTROMECHANICAL OR INERTIAL WIRE COVERED.
K--TELEMETERING.
L--COUNTERMEASURES.
M--METEOROLOGICAL.
N--SOUND IN AIR.
P--RADAR.
Q--SONAR AND UNDERWATER SOUND.
R--RADIO
S--SPECIAL TYPES, MAGNETIC, ETC., OR COMBINATIONS OF TYPES.
T--TELEPHONE (WIRE).
V--VISUAL AND VISIBLE LIGHT.
W--ARMAMENT (PECULIAR TO ARMAMENT, NOT OTHERWISE COVERED).
X--FACSIMILE OR TELEVISION.
Y--DATA PROCESSING.

A--AUXILIARY ASSEMBLIES (NOT COMPLETE OPERATING SETS USED WITH OR PART OF TWO OR MORE SETS OR SETS SERIES).
B--BOMBING.
C--COMMUNICATIONS (RECEIVING AND TRANSMITTING).
D--DIRECTION FINDER, RECONNAISSANCE, AND/OR SURVEILLANCE.
E--EJECTION AND/OR RELEASE.
G--FIRE-CONTROL OR SEARCHLIGHT DIRECTING.
H--RECORDING AND/OR REPRODUCING (GRAPHIC METEOROLOGICAL AND SOUND).
K--COMPUTING.
L--SEARCHLIGHT CONTROL (INACTIVATED, USE G).
M--MAINTENANCE AND TEST ASSEMBLIES (INCLUDING TOOLS).
N--NAVIGATIONAL AIDS (INCLUDING ALTIMETERS, BEACONS, COMPASSES, RACONS, DEPTH SOUNDING, APPROACH, AND LANDING).
P--REPRODUCING (INACTIVATED, DO NOT USE).
Q--SPECIAL, OR COMBINATION OF PURPOSES.
R--RECEIVING, PASSIVE DETECTING.
S--DETECTING AND/OR RANGE AND BEARING, SEARCH.
T--TRANSMITTING.
W--AUTOMATIC FLIGHT OR REMOTE CONTROL.
X--IDENTIFICATION AND RECOGNITION.
Y--MULTI-FUNCTION

[1] NOT FOR US USE EXCEPT FOR ASSIGNING SUFFIX LETTERS TO PREVIOUSLY NOMENCLATURED ITEMS.

20.484

Figure 3-22.—AN system.

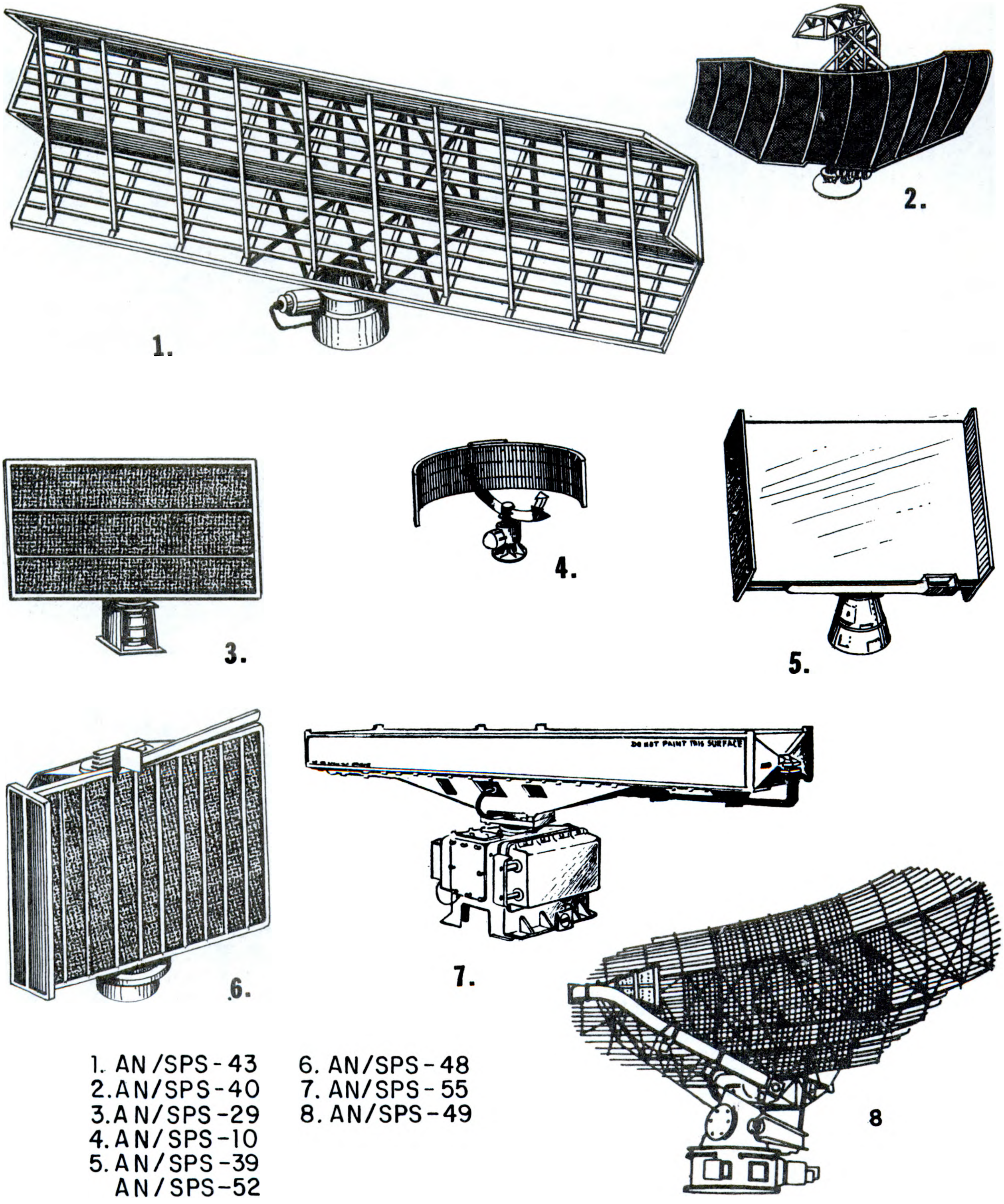
Control Station and Combat Information Center (WCS/CIC) area for target engagement evaluation. Electronic counter-countermeasure (ECCM) features, controlled at the radar, improve the display when jamming environments are encountered.

Two-Coordinate Radars

An alternate source of air target information for a weapon system is a two-coordinate radar. Two-coordinate radars are the primary means for the detection of long-range air targets. These radars (AN/SPS-29, AN/SPS-37, AN/SPS-40, or AN/SPS-43) provide coarse range and bearing information and IFF capabilities similar to those of the three-coordinate radars. They do not, however, provide elevation information.

Surface Search/Navigation Radars

Radar Sets AN/SPS-10, AN/SPS-55, and the new AN/SPS-67 are short-range, two-coordinate, narrow-beam radars capable of good discrimination in range and bearing for surface search surveillance and low flying aircraft. These radars are becoming more important today because of their capability to detect low flying antiship missiles.



167.714

Figure 3-23.—Search radars.

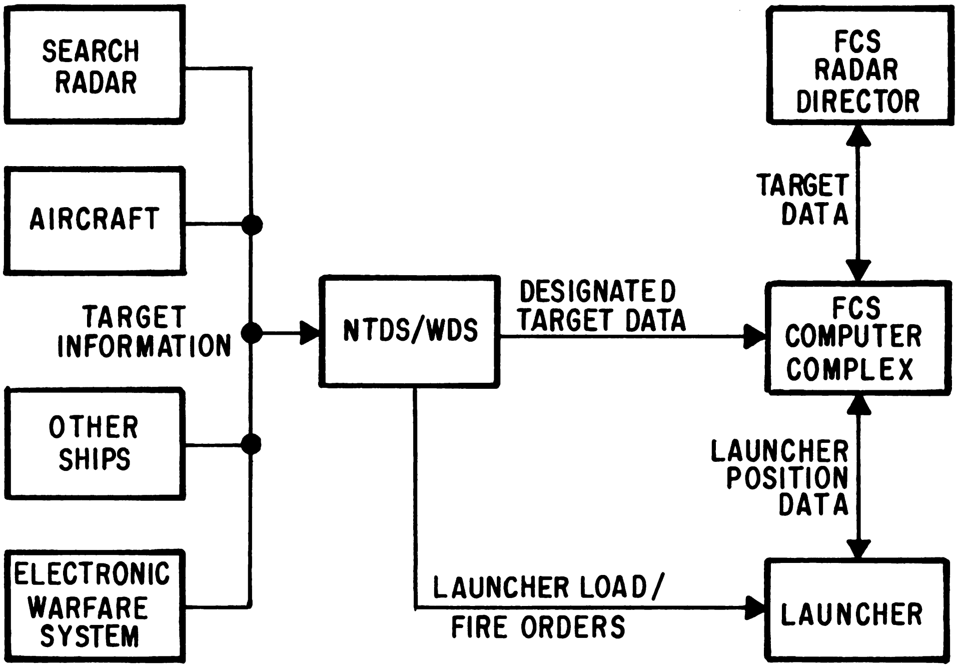
Electronic Warfare Support Measures (ESM)

Electronic warfare support measures (ESM) equipment is used to detect, locate, analyze, and record electronic emissions throughout the electromagnetic spectrum. This provides your ship with the capability to gain tactical and strategic intelligence on enemy electronic activity of all types, while remaining undetected by the enemy. The activity could be an enemy radar, which could then be identified according to its potential threat, or it could be an active guidance transmitter on an incoming enemy missile. In either case, the ESM capability is a factor in your ship's overall defensive capability.

The fundamental piece of equipment in an ESM system is the intercept receiver, either narrow-band or wide-band. The receiver detects enemy rf emissions as a function of frequency and provides selected signal outputs to displays, signal analyzers, recorders, and warning devices. Outputs may also be used to automatically gate electronic countermeasures (ECM) equipment, including deception repeaters and chaff launching devices. Your ship may have one or more of the following ESM equipments: AN/WLR-1, AN/WLR-3, AN/WLR-8(V), AN/WLR-11A, SLR-12 and the newer AN/SLQ-32(V).

Naval Tactical Data System/ Weapon Direction System

The Naval Tactical Data System (NTDS) is a high-speed, digital-data processing, display, communication, and data conversion system that provides tactical data used to improve fleetwide defense against all types of enemy targets. The NTDS coordinates collection of tactical data from sources both internal and external to ownship. Ownship data inputs to the NTDS are received primarily from search radars, IFF equipment, electronic warfare (EW) equipment, sonar, and navigation and



167.715

Figure 3-24.—Typical TARTAR weapon system block diagram.

communications equipment. These data inputs are supported by inputs received from other ships, aircraft, and shore stations via data links. The NTDS correlates this data for a clear representation of the tactical situation, processes the data as required to aid in the decision-making process, and communicates all action decisions to the Weapon Direction System (WDS).

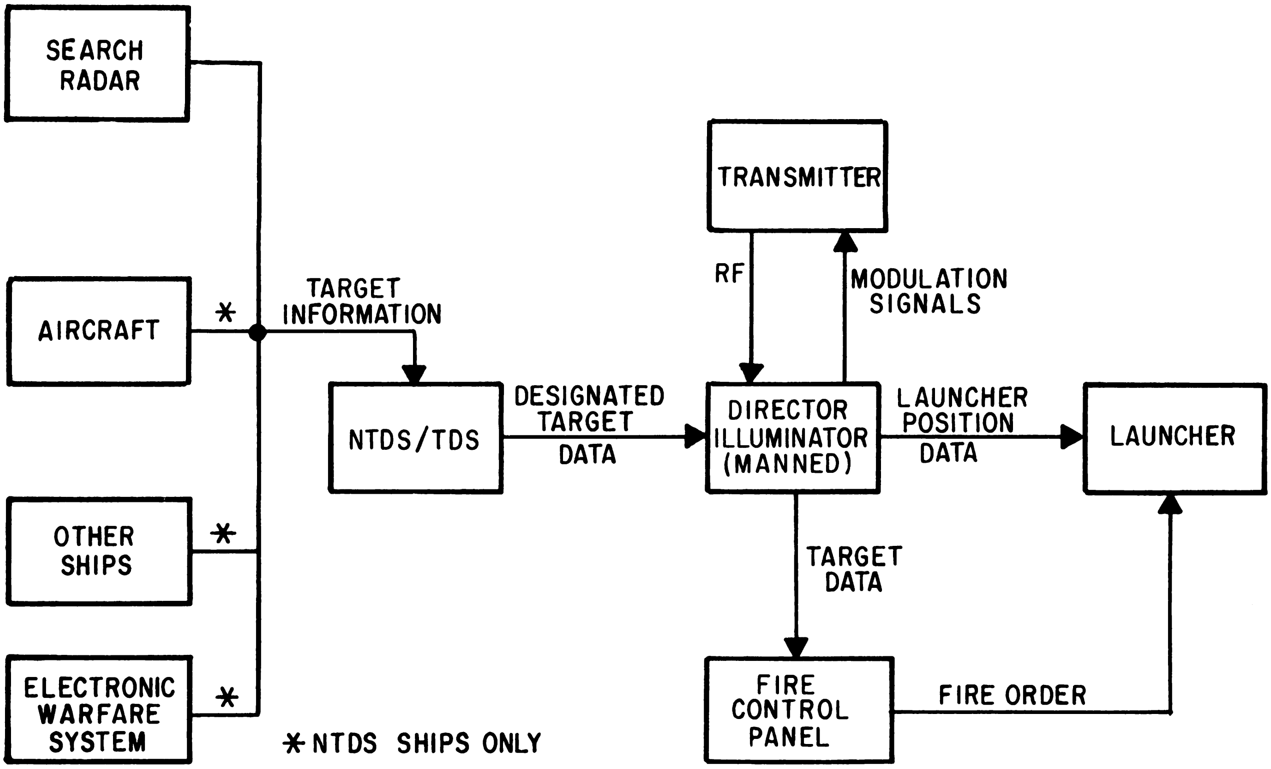
The WDS enables centralized control and monitoring of target engagements assigned to the missile fire control system. The WDS is used to initially evaluate targets, assign the targets to the missile fire control system, select the missile type and number to engage the targets, and evaluate the engagement results. The WDS ancillary equipment provides control of the missile fire control systems, designation of optically tracked targets, and firing of missiles. In addition, the WDS ancillary equipment also provides indications of missile fire control system radar/director train angles, missile fire control system tracking status, occurrence of missile flight, and a means of recommending changes to the ship's course to provide an unobstructed firing zone.

The relationship between the NTDS/WDS and the weapon systems is illustrated in the TARTAR and Basic Point Defense block diagrams shown in figures 3-24 and 3-25. Most other weapon systems are fundamentally similar to the TARTAR block diagram.

TRACKING

The process of maintaining the fire control radar rf energy beam on the target is called tracking.

For a fire control system (FCS) to implement the solution to the fire control



167.883

Figure 3-25.—Basic Point Defense weapon system block diagram.

problem, it must receive information on target position (range, bearing, and elevation), and target motion. Target tracking provides this information, which is the principal input to any guided missile fire control system.

The Director or Radar Set

The director or radar set can search for, detect, acquire (lock-on), and track a target. Let's stop and consider the terms "director" and "radar set." A gun director may contain a radar and/or optics for tracking and ranging, and it is usually manned. A missile director, on the other hand, has no optical tracking device or range finder. It relies primarily upon its radar for tracking; therefore, it is not manned in the sense that an individual is located inside the antenna supporting structure. True, there is an operator in the radar control room, but the primary function of this person is to monitor the equipment. In the rest of this discussion, we use the term "radar set," rather than director, because that name is more descriptive of the function of a missile director.

The radar set described here is an automatic target tracking and missile guidance radar. It normally receives target designation signals from the weapon direction system via the fire control computer. The designation signals position the radar set to the designated range, bearing, and elevation. If the radar set does not acquire the target immediately, the fire control computer originates a search program which causes the radar set to look for the target. If the ship has more than one fire control system, designation between systems is possible. Designation from another fire control system, called "interdirector designation" or "IDD", is very accurate and a search program is not needed.

When the radar set acquires the target in range, bearing, and elevation, the radar set locks on the target and starts to track it. Tracking circuits within the radar set automatically keep its tracking beam on the target. Target position is continuously transmitted to the computer. The computer and the radar set working together solve for the target's rate of movement about the ship by calculations based on the line-of-sight movements.

The radar not only tracks the target, but also transmits rf beams to control the missile and guide it to the target. As used with semiactive homing missiles, the fire control radar transmits a narrow pulsed beam of rf to track the target. Continuous-wave rf is also transmitted to illuminate the target, as described in chapter 2. The missile locks on the rf reflected from the target and homes in on it.

Some systems have the capability to track the target with the cw illuminator, either as the primary tracking mode or as an addition to normal pulsed tracking.

The radar set consists of two major groups of equipment: an antenna group, and a control and power group (fig. 3-26). The antenna group, which is located above deck, consists of a pedestal upon which is mounted the antenna and the necessary electrical and mechanical components required to stabilize and position the antenna. Here, too, are located the rate gyros that space stabilize the antenna, and thus the radar beams. Space stabilizing the antenna corrects for the roll and pitch of the ship. More will be provided on this, shortly.

The control and power equipment group is located below deck in a compartment usually called the radar room. This room contains the radar consoles used to operate, monitor, and control the radar set. Also located in the radar room, or in a nearby equipment room, are the cabinets containing the power supplies that provide the operating voltages for the various units in the radar set.

The transmitter, receiver, and related microwave circuitry are usually located below deck along with the control and power group.

Tracking From a Moving Ship

As an aid in understanding the operation of gyros in a tracking loop, a simple tracking loop which can track a target in a vertical plane will be analyzed.

The gyro maintains a direction that remains fixed in space in the presence of motion, and yet can be changed in response to a command signal. An illustrative single-degree-of-freedom gyro is

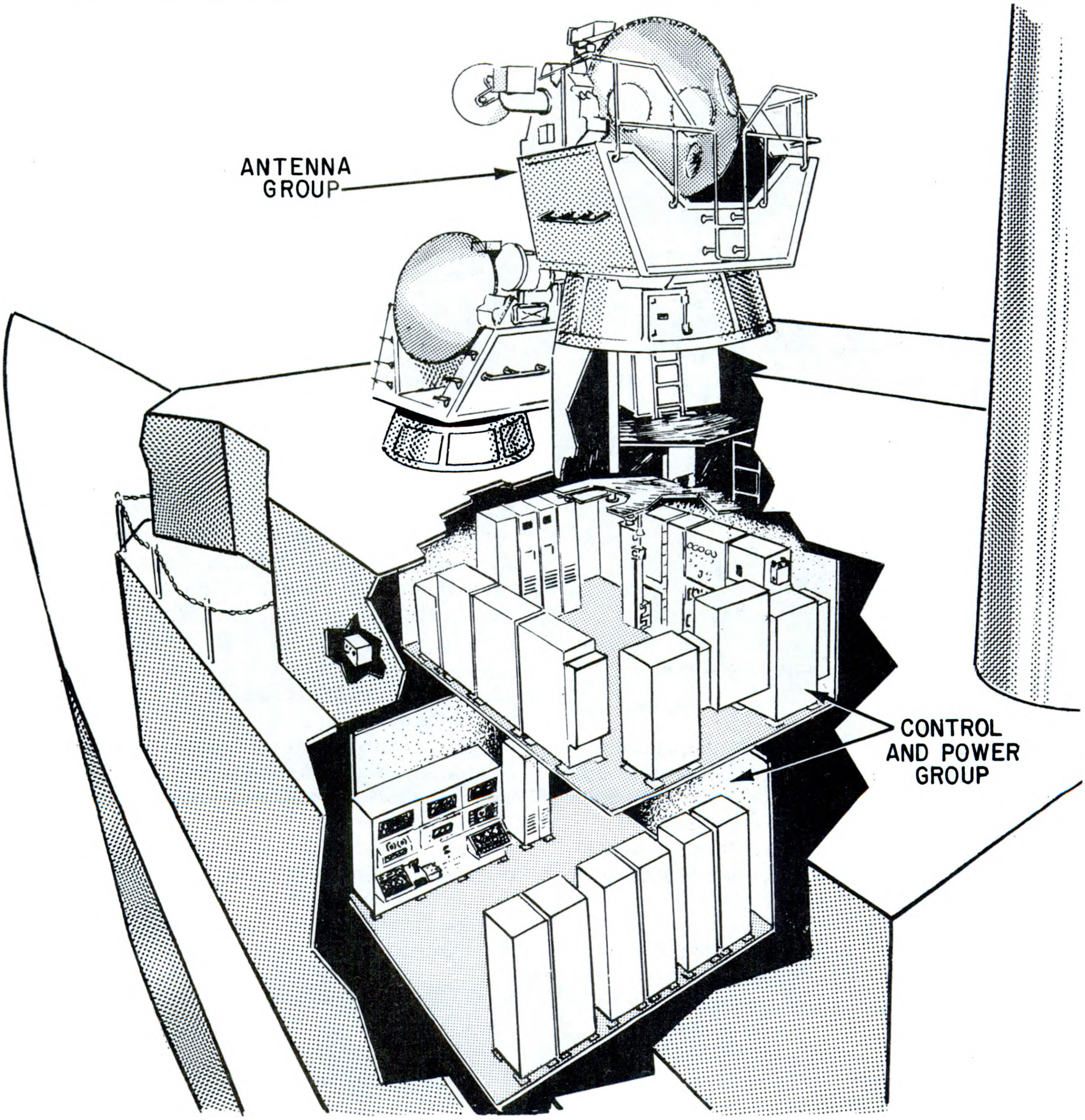
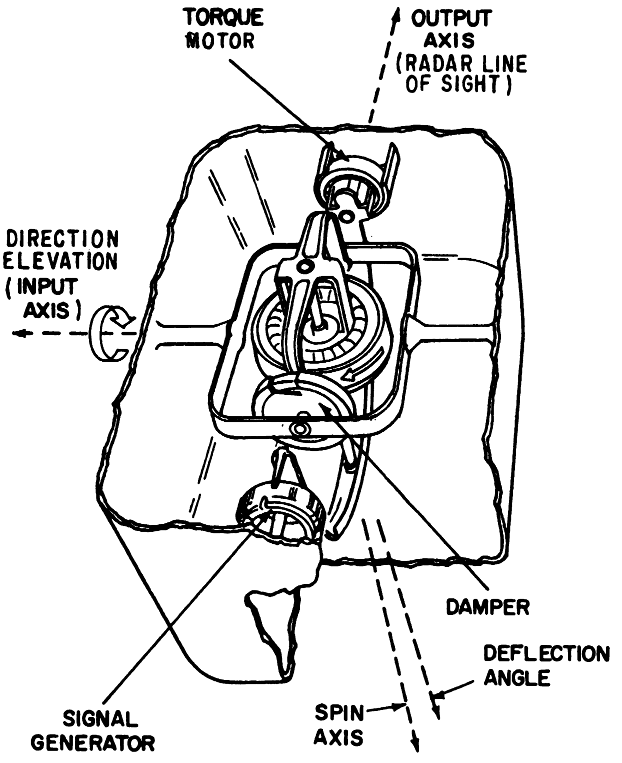


Figure 3-26.—Above deck and below deck equipment groups.

shown in figure 3-27. When this gyro is used in a tracking loop, the configuration that results is similar to the one shown in this figure.

The radar antenna is the device which receives the rf energy reflected from the target. When the target and ship are relatively (in terms of bearing and elevation) motionless, the system is at rest. The radar rf tracking axis is nulled with the line of sight to the target, therefore the antenna positioning signals from the tracking


TORQUE MOTOR
OUTPUT AXIS (RADAR LINE OF SIGHT)
DIRECTION ELEVATION (INPUT AXIS)
DAMPER
DEFLECTION ANGLE
SIGNAL GENERATOR
SPIN AXIS

167.718

Figure 3-27.—Single-degree-of-freedom gyro.

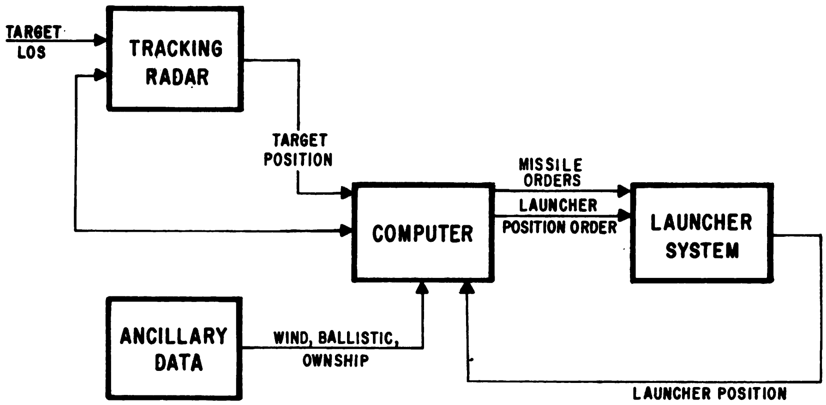
error circuits are zero. The gyro remains fixed with reference to space, and the signals to the antenna drive system are zero. But, if the ship were to pitch downward, the antenna, being mounted on the ship, would tend to move downward also. This provides a rotational velocity of the gyro case which causes the gyro to precess at a rate proportional to the downward pitching motion. The precession is detected by a signal generator, the output of which activates the antenna drive system to move the antenna upward at the rate equal to the downward pitching motion. In this manner, the antenna is maintained stabilized with respect to space as represented by the position of the gyroscope.

When the target moves, the line of sight to the target is displaced from the rf tracking axis as indicated by the antenna position. The tracking error detection circuits produce correction signals to drive the gyro torque motor. The action of the gyro torque motor has two effects. First, it causes the signal generator to produce a signal which causes the antenna to move to follow the target, and consequently, causes the rf tracking axis to follow the line of sight to the target. Second, it causes the gyro to reposition itself with respect to space; that is, to reposition the gyro output axis to align itself with the line of sight to the target.

COMPUTATION

The basic functions of the fire control computer are the computations of lead angle, launcher orders, missile orders, and radar repeat back data.

As its input, the computer (fig. 3-28) receives the target position from the tracking



167.720

Figure 3-28.—Computer subsystem.

radar and the necessary ancillary data. The position of the tracking radar is compared with and maintained coincident with the line of sight of the target (rf axis) by the tracking system. From the input data, the computer generates the intercept point and the computed position to which the launcher should be driven. When the launcher is assigned to the target, the launcher drive system then drives in response to the computer's launcher position order. The launcher drives until actual launcher position and the computed launcher position are coincident.

Missile orders are transmitted to the missile(s) while on the launcher. Actual response to the orders, however, takes place during missile flight.

Radar repeat back data is used in the NTDS/WDS displays to update fire control radar status and to provide the NTDS/WDS console operators with fire control problem solution data.

Computer decisions and computations are expanded later in this discussion.

For simplification and accuracy of operation the computations must be performed in some reference frame which has been selected to permit a simplified solution to the fire control problem. Data received by the fire control computer is rarely measured in the reference frame and coordinate system which are used for computation. Because different frames and systems are used, the input data, particularly the tracking data, must be converted to the frame in which the data is to be employed. When the prediction angle is determined, it must be converted to the frame in which the missile launcher operates. One of the major functions of the computer, then, is to convert the data to useful forms.

TYPES OF COMPUTERS

A computer is a device or a machine in which physical or electrical operations perform mathematical computations to provide logical or numerical results. Computers are usually classified as one of two basic types—analog or digital. Analog computers essentially deal with a continuous measurement of a function, while digital computers deal with counting discrete values of a function. Basically, the analog computer measures and the digital computer counts.

The first Navy computer, designed to solve the gun fire control problem against surface targets, was known as the Rangekeeper Mark 1. Later, a gun director and a computer for use against aircraft were put on ships. In 1939, the Mark 1 Computer was installed in the fleet as the primary computer for defense against aircraft. These pre-World War II computers used mechanical devices such as cams and gears to accomplish problem solutions. With the advent of jet aircraft, faster computers were needed. This led to electromechanical analog computers that used resolvers, potentiometers, electrical summing networks, and the like.

Digital computers were first used to handle the increasing amount of tactical information processed by the Combat Information Centers (CIC). This developed into the Naval Tactical Data System mentioned earlier. More recently, fire control systems have been updated to use digital computers which solve the fire control problem.

Analog Computers

An analog computer is one in which data are represented by physical magnitudes, such as the angle of rotation of a shaft, or by the magnitude of an electrical voltage or current. The basis of analog computation is the establishment of an analog or scale factor between the data and the computing mechanisms in the computer. The limit of precision of an analog computer is determined by how precisely the scale is read, which is limited by how accurately gears are ground, or by how precisely resistors, inductors, and capacitors are manufactured. The continuous measurement of a variable in an analog computer makes it useful in fire control problems dealing with varying inputs, such as would be presented by an aircraft problem. On the other hand, because the computer operates on a continuous basis, it cannot jump from one problem to another. Switching is possible, but it involves a loss of time, thus slowing down the speed of a solution. Therefore, analog computers are usually used for solving only one problem at a time.

Although once the most common type of computer in fire control, analog computers are gradually being replaced by the newer digital computers. However, even in digital systems, various isolated computing functions may still be performed by simple types of analog devices.

Digital Computers

A digit is a mathematical symbol used to represent a positive number smaller than the base of the numbering system of which it is a part. For example, in the decimal system, a digit is one of the symbols 0 through 9; while in the binary system, only the symbols 0 and 1 are used.

A digital computer, then, is a device which uses numerical equivalents of data to solve problems. These problems involve mathematical computations and logic decisions. The numerical equivalents may be expressed as binary, octal (base eight), decimal numbers, etc. In an electronic digital computer, the numerical equivalents are generally expressed as binary numbers. Binary numbers, in turn, are represented within the computer by discrete voltage or current levels. For example, a binary one could be represented by +5 volts and a binary zero by 0 volts.

Digital computers are capable of a higher degree of accuracy than analog computers. That accuracy depends only on the size of the smallest increments of the particular values used. This is comparable to whether a digital watch displays minutes only or minutes and seconds.

When digital computers are used, there is usually a need for analog-to-digital conversion. For a description of the conversion methods and digital computers in general, refer to *Digital Computer Basics*, NAVEDTRA 10088-B.

TYPICAL COMPUTATIONS AND DECISIONS

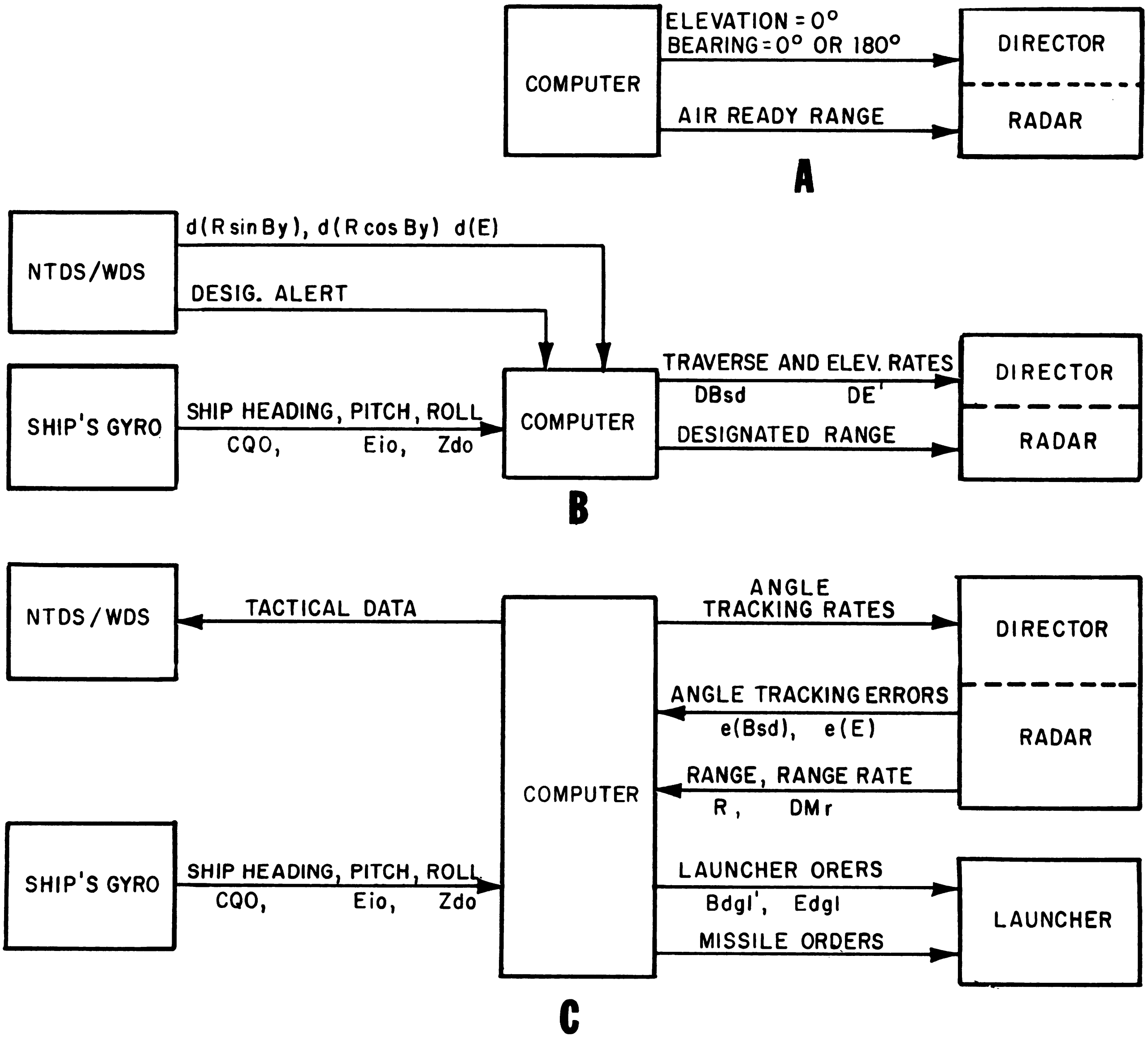
The operations that a fire control computer performs are many and varied. Rather than go into the details of each of the operations of the many types of computers, we will discuss the roll of a computer in a typical guided missile fire control system (GMFCS). This involves not only mathematical computations, but also logical decisions.

To accomplish these functions, the computers must receive large amounts of data and control signals from other parts of the weapon system. After the computations and decisions are made, the computer then outputs data and control signals to other parts of the weapon system. Figure 3-29 shows the computer's relationship to the other parts of the GMFCS.

First, consider the computer's interface with the other components of the weapon system during the three major modes of operation—air ready, designate, and track.

Air Ready Mode

When the GMFCS is energized, not tracking, and not receiving a designation alert signal, the computer places the GMFCS into the air ready mode of operation. The computer generates control and data signals to position the director to its air ready position (usually 0° elevation and 0° or 180° relative bearing, depending on whether the director is located fore or aft) and the radar range to its air ready value (fig. 3-29A). The GMFCS is at the ready awaiting a designation.



167.884

Figure 3-29.—GMFCS data flow in: A. air ready mode, B. designate mode, and C. track mode.

Designate Mode

When a target is evaluated as a threatening target, the NTDS/WDS sends a designation alert signal to the computer to put it in the designate mode. The computer then receives target position data from a designation source. The computer generates signals to position the director to the designated target position (traverse and elevation) (fig. 3-29B). The computer also causes the radar range to drive to the designated position.

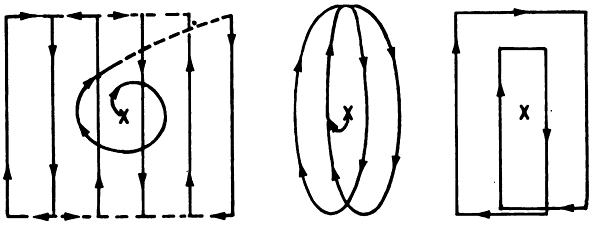
Depending on the source and reliability of the designated data, the computer may generate a search program to aid the radar in target acquisition. The search program modifies the designated bearing and elevation data to the director, causing the radar beam to sweep in a pattern about the designated position. Figure

3-30 shows what these patterns might look like. The type and size of the search pattern is determined by the accuracy of the designated data.

Track Mode

Once the radar has received a predetermined number of target echo returns, the search program stops and the computer sends the director back to where the target echos occurred. The radar then locks on the target in range and sends a track or lock-on signal to the computer. After this signal is maintained for a prescribed interval, the computer generates an on-target control signal to place the GMFCS in the track mode.

Target tracking is accomplished through a closed loop consisting of the radar, director, and computer. The radar senses the angular errors between its antenna boresight axis and the target position in the traverse and elevation planes. These errors and target range and range rate are transmitted to the computer (fig. 3-29C). The computer makes up the relative motion rates to keep the director on target.



167.885

Figure 3-30.—Search patterns.

During the track mode, the computer generates and transmits tactical data to the NTDS/WDS for evaluation of the target being tracked. Also, the computer generates launcher position orders and missile preflight orders for the type of missile selected for firing.

COORDINATE CONVERSION

Coordinate conversion is the process of transforming vector components from one coordinate system to another by electrical and/or mechanical means.

In general, the computation of the fire control solution is accomplished in geometrically stable coordinates. Stable quantities are those that are referenced to the horizontal and vertical planes.

If measured tracking data is acquired in an unstable frame, and the fire control computer operates in a stable frame, a transformation from unstable coordinates must be made at the computer input. Similarly, if the launcher operates in an unstable frame, the reverse transformation is required at the computer output (fig. 3-31).

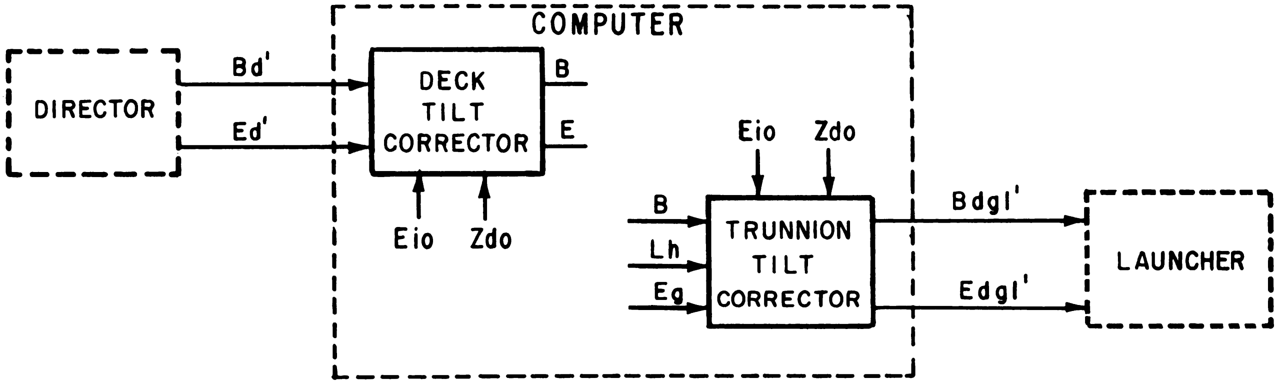


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Figure 3-31.—Coordinate conversion.

The cause of quantities being unstable is that certain elements of the weapon system, such as the director and launcher, are rigidly attached to the ship's deck.

As mentioned earlier in this chapter, the ship rolls and pitches. Therefore, roll and pitch information from the ship's gyro compass is needed. Figure 3-32 is an example of how roll affects a quantity such as elevation. With no roll, the director is pointed at an angle that is 45° above both the deck and horizontal planes. With a 10° roll, the director elevation (measured from the deck plane) is 35°, while the target's elevation is still 45° above the horizontal. Without compensation for roll, the computer would think that the target's elevation angle was 35°.

MISSILE CONTROL

When the line of sight to the target has been established and the prediction angle (launch and intercept point) has been determined, the fire control problem has been solved. Next, the solution must be put into effect. The launching system must launch the missile in the proper direction to put the missile in the correct position and attitude in space so that a homing missile will lock on the target or a beam-rider missile will be in the capture beam.

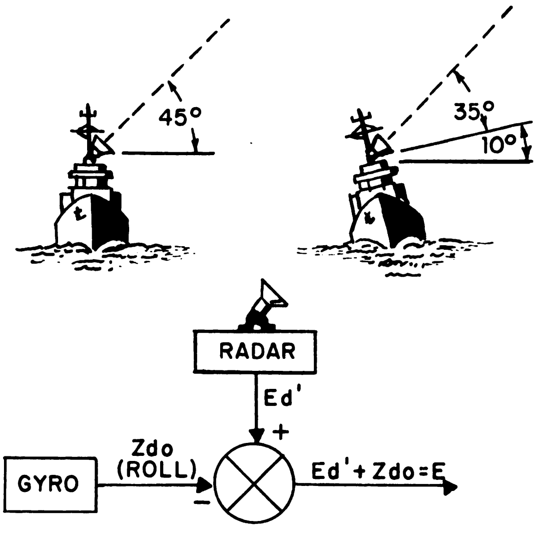

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Figure 3-32.—Effects of roll.

A guided missile must receive orders to follow. The orders may be given prior to launch, during flight or both.

LAUNCHERS

Some launching systems are so big and complex that they are fixed and require that the launcher return to a predetermined angle of elevation for loading. The loading angle may be vertical, horizontal, or near the horizontal. This loading at a prescribed angle of elevation is usually coupled with loading at a preset position in train. A typical TERRIER launcher installation (fig. 3-33) illustrates the necessity of the launcher returning to predetermined angles of train and elevation in order for the loading operation to be accomplished.

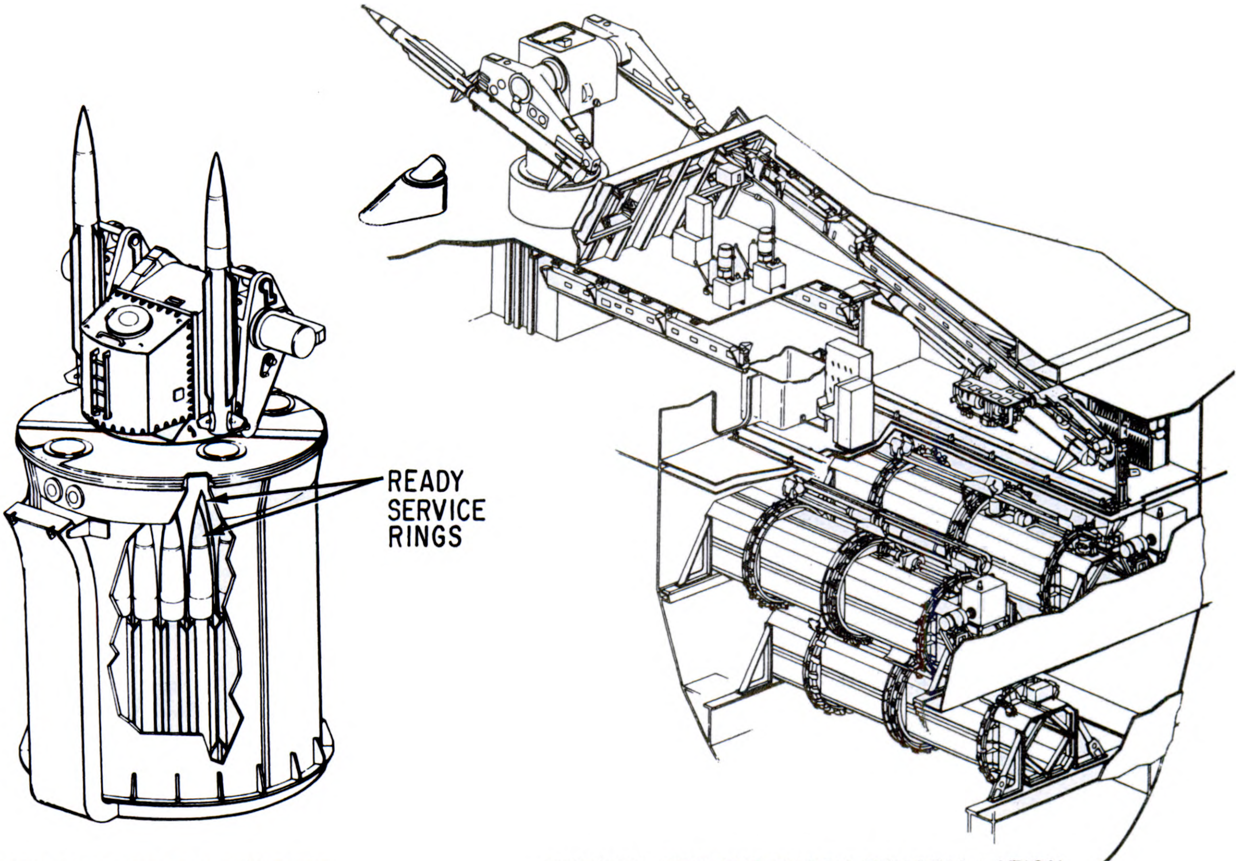
With some missiles (usually those with integral propulsion systems), loading may be conducted by making the line of missile transfer coincident with the train axis of the launcher. This can be done by rotating the magazine or the magazine cover, such as with the TARTAR launcher shown in figure 3-33.

Another type of launcher, the box type (fig. 3-33), is used with SPARROW III. This launcher additionally serves as the magazine. There is no loading involved during normal operation. Canister and coffin launchers also are self storing launchers.

In general, the launching system must respond to certain types of orders, such as what to launch, where to launch, and when to launch. These orders are electrical signals normally sent either from the NTDS/WDS or the fire control computer to the launching system, via the fire control switchboard.

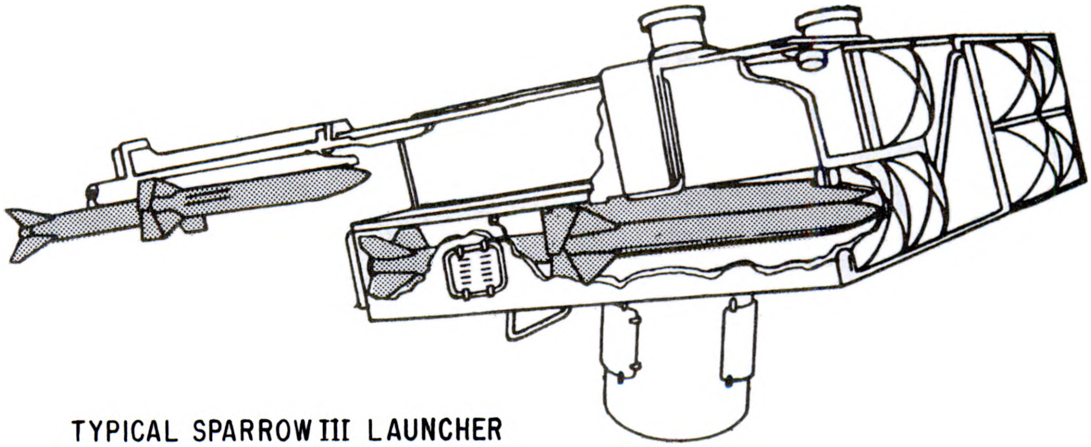
Selection of a Missile

A launching system often has several types of missiles stored within its magazine, so it must receive orders regarding the type or types of



TYPICAL TARTAR LAUNCHER
AND MAGAZINE

TYPICAL TERRIER MISSILE INSTALLATION



TYPICAL SPARROW III LAUNCHER

167.722

Figure 3-33.—Guided missile launching systems.

missiles to be launched. There may be a choice between the modes of a type of missile or even between types of missiles. For example, TARTAR ships can fire both STANDARD and HARPOON missiles from their launchers.

In addition to the type of missile, the launching system must know how many missiles to launch. For example, a guided missile launching system may fire one rail or two rails at the same time, and do it either once or continuously.

Position Orders

The signals that are used to position the launcher are called launcher orders and they usually originate at the fire control computer, or in some cases, at a control panel. These are usually dual-speed synchro signals with the symbols Bdgl′ and Edgl′. Once at the ordered position, the launcher is then continuously updated by d.c. rate signals, DBdgl′ and DEdgl′. These signals allow for smooth movement of the launcher while it is responding to the fire control problem solution.

GUIDANCE

Guided missiles have self-contained guidance or remote guidance which provides some degree of inflight control. The inflight control may exist only for a short period during flight, or throughout the entire flight. For guided missiles, it is not simply a problem of finding the direction to aim the missile (launcher positioning), but one of guiding the missile. There are missiles which combine the features of more than one type of guidance system, such as missiles which are remotely guided from the launching ship to the general vicinity of intercept and then guided to intercept by their own homing devices.

Homing

As discussed in chapter 2, homing systems can be divided into three types, depending on the source of the energy detected by the tracking sensor within the missile. The three types of homing are active homing, semiactive homing, and passive homing.

ACTIVE HOMING.—In an active homing system, the transmitter of energy which illuminates the target and the receiver which receives the reflected energy from the target are both contained in the missile. A simple homing system consists of a transmitter and receiver of microwave energy for target detection and tracking, a computer to calculate the required missile line of sight position to the target, and missile control equipment to direct the missile in response to the computer orders to intercept the target.

Active homing has several advantages:

- Once homing starts, the missile is completely independent of energy transmitted from an external source and of any external guidance information.

- The fire control system of the launching ship may engage another target as soon as homing is initiated.

- Long-range target intercept is possible beyond the accurate fire control radar tracking range.

- The launching ship has greater flexibility since it can maneuver once homing is initiated.

SEMIACTIVE HOMING.—In a semiactive homing system, the transmitter of energy which illuminates the target is located outside the missile, on the launching ship. The semiactive homing system operates in the same manner as the active homing system. Because the energy transmitter is not in the missile, but instead is on the much larger launching ship, the size and weight of the transmitter can be much greater. This permits the use of long-range, high-power transmitters.

Since the missile operates solely on energy which originates in the transmitter on the launching ship, the FCS cannot break off the attack on the target once the missile is launched. Once the missile with active homing is launched, the FCS is free to engage another target. With semiactive homing, however, the FCS must continuously participate in the engagement until intercept occurs. A way to overcome this disadvantage is by using a different type of guidance, such as command guidance, during most of the missile's flight. Command guidance does not require continuous illumination from the FCS, as it uses a separate rf data link. Thus the illuminator is used for semiactive homing only for the terminal phase, which results in the FCS being required only for the last few seconds at the end of the missile's flight.

PASSIVE HOMING.–The third form of homing is passive homing, which relies solely on energy emitted by the target. Because a passive homing system does not require an internal transmitter, it has the advantages of a relatively light weight missile, as in a semiactive homing system, and missile independence of the launching ship, as in an active homing system.

Command Guidance

A typical command guidance system, as discussed in chapter two, uses two radars to separately track the target and missile. The fire control computer is provided with continuous position data from both radars. The computer uses this data to generate the missile flight path control orders necessary to maintain the missile on an intercept course. These control orders are sent to the missile via an rf data link.

Another example of a command guidance system is a beam riding system. A guidance beam is used to provide a direction to the target along which the missile must go. The missile must then determine its location with respect to the beam and steer to keep itself centered in the beam.

MISSILE ORDERS

A guided missile needs information in the form of signal inputs in order to carry out its mission. As indicated earlier, information may be supplied before or during missile flight, or at both times. Inputs applied before launch are normally referred to as missile orders.

These orders are constantly updated until the time of firing. Missile orders vary from system to system and from missile to missile, so we cannot discuss all the possibilities. We will, however, discuss several commonplace missile orders. Remember that the exact name may vary between systems, while the function itself remains the same.

Missile Roll Order

While the missile is on the launcher rail, prior to launch, its vertical axis may rotate (roll) due to the ship's roll and pitch. If the missile were fired from this position (vertical axis tilted), the missile's gyros would keep it in this attitude (vertical axis tilted). This could possibly result in a miss. The fire control computer computes the amount of missile cross-roll angle and sends a correction signal, mZol, to the missile. This signal causes the missile's vertical axis to return to the true vertical axis once the missile has left the rail.

Seeker Orders

Seeker orders (sometimes referred to as head aim) are used to initially position a homing missile's seeker (receiver) antenna. As mentioned in the previous chapter, this type of missile is fired at a collision point and not directly at the target. Therefore, prior to or just after launch, the seeker must be "slewed" so that it is pointing at the target in order to detect a reflected rf signal.

Variable Navigation Ratio

We have already discussed proportional navigation in chapter 2. In brief, the missile attempts to maintain successive lines of sight parallel to each other. (Refer to figure 2-14B). If the target changes course, an angular change between the seeker head position and the missile longitudinal axis results. This angular change is sensed by the missile's seeker head and is transformed into error signals that redirect the missile along a new course. The missile heading changes at a rate that is proportional to the angular rate of change in the missile-to-target line of sight. This proportionality constant is the navigation ratio of the missile. The navigation ratio, which is really the missile system steering gain, determines the rate at which the missile turns for any given error signal.

In order to increase the kill probability against long-range targets, the proportional navigation course is modified by a fire control computer output of Variable Navigation Ratio. The VNR signal reduces the steering gain during the early part of the flight. This low steering gain and the superelevated launch angle allow the missile to ascend to a higher altitude where there is less aerodynamic drag. After reaching the higher altitude, the missile gradually turns toward the target before plunging downward to the point of intercept (fig. 3-34). This action preserves the high missile velocity acquired during boost and thus provides the missile with greater maneuverability during the final portion of the flight.

Doppler Predict

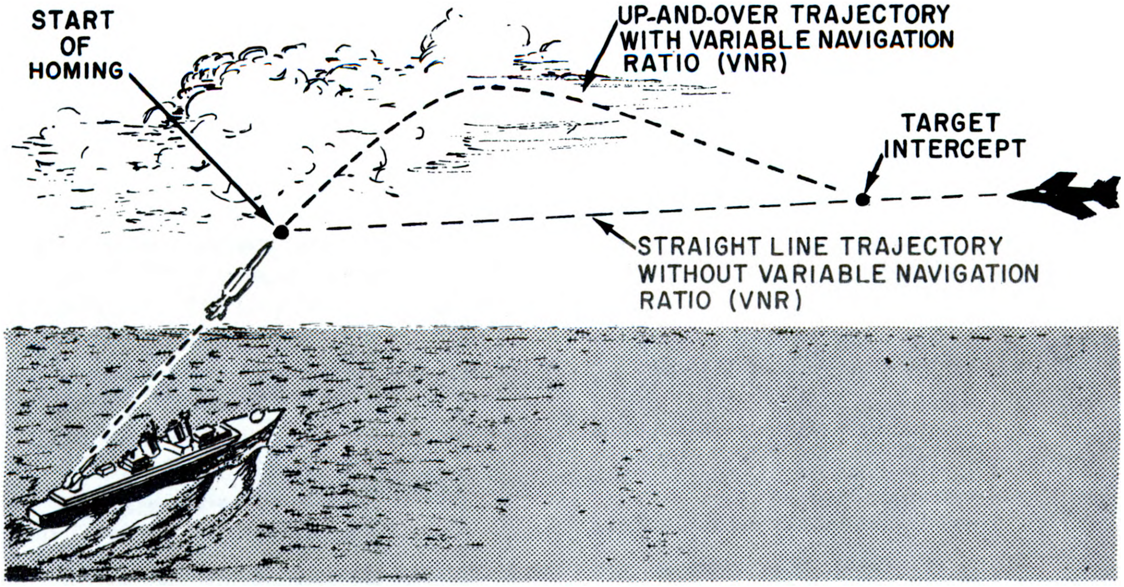
During flight, guidance information is derived by the missile in the form of a Doppler frequency shift between the signal reflected from the target and the signal received directly from the shipboard illuminator radar. This Doppler frequency shift is proportional to the missile-to-target closing range rate. The Doppler Predict signal is proportional to a fire control computation of what the missile-to-target closing velocity should be. The Doppler Predict signal determines the frequency at which the missile receiver starts searching for the target Doppler signal.

WEAPON SYSTEM OPERATIONAL PHASES

In summary, the overall task of any guided missile weapon control system may be generally described as controlling the delivery of a warhead or payload to the target.

TARGET DETECTION

The target detection phase involves the surveillance and detection or discrimination of any enemy or unidentified targets that appear within the surveillance field. This detection is normally achieved by the ship's air search and surface search radars, and in some cases by the ship's fire control tracking radars and electronic warfare (EW) sensors.


START OF HOMING
UP-AND-OVER TRAJECTORY WITH VARIABLE NAVIGATION RATIO (VNR)
TARGET INTERCEPT
STRAIGHT LINE TRAJECTORY WITHOUT VARIABLE NAVIGATION RATIO (VNR)

167.887

Figure 3-34.—Effects of variable navigation ratio.

TARGET CLASSIFICATION

This phase consists of classification of the detected target and identification. Identification of the target determines its friendly or unfriendly character.

To afford protection to friendly forces, IFF (identification friend or foe) electronic equipment is used in conjunction with the radar systems. Through the use of IFF equipment, radar detected targets can be identified as friendly without resorting to verbal communications or visual identification. An IFF transmitter emits a signal on a particular frequency. The signal is received by the target in question and in turn transmits a coded signal back to the ship. If the ship's receiver is set to the particular coded pulse chain that is returned, it automatically signals the operators that the target is friendly. If no signal is returned or the code is incorrect, the target is assumed to be unfriendly.

TARGET LOCATION

The target location phase consists of locating the target relative to the ship with sufficient accuracy for effective weapon employment, and the maintaining of radar contact with the target.

Target location radars include those which gather the information necessary to define a target's location for designation to the fire control system. The fire control system will lock on and track the target.

Tracking is essential to target interception, since it provides the necessary flow of data (precise bearing, elevation, and range) which is so important for target location. This may be accomplished by two or more separate radars, in which a search radar detects the target and locates it with sufficient accuracy to supply information to a designated fire control tracking radar.

A target can defeat a radar system in a variety of ways. Any countermeasures which give false target information, such as chaff and decoys, can be effective, since they tend to obscure exact target position and may cause an automatic tracking radar to "break track" and lose the target by overloading the radar system with false targets. In these instances, the most effective counter-countermeasure is a highly trained operator and an accurate discerning device, built into the radar, that is capable of distinguishing false targets from real ones.

Jamming techniques are similarly effective because exact target position is lost and cannot be tracked in the jamming signal. Missile homing devices, radar receiver delay circuits, and random pulse-repetition frequency (prf) of output are all effective methods of countering jamming techniques.

Spoofing with electronically simulated targets is also employed to overload and fool target tracking radar systems. Again, coding or randomness of radar outputs can successfully defeat this form of countermeasure.

MISSILE SELECTION

This phase involves selection of the optimum type of missile, consistent with the mission of the ship and its capabilities, and the designation of a specific fire control system to destroy the target. For example, in a guided missile cruiser, on detecting a threatening air target, the weapon control officer selects either a beam-riding or homing missile and designates a specific guided missile fire control system to the target with that type of missile.

MISSILE LAUNCHING

The missile launching phase is concerned with the safe and effective launching of a missile into the desired flight path.

To fulfill the operational requirements imposed during the launching phase, a launching system performs certain specific functions: missile storage, loading, and launching.

The magazines and ready service storage area provide for the safe, protected storage of the supply of missiles needed to engage the enemy.

Loading is accomplished by moving the missile from its storage area to the launcher.

The fundamental unit of a launching system is the launcher, which accomplishes flight initiation of the missile. Precision of launcher positioning orders at launch does not dictate the resulting kill probability of the target, since the guided missile flight path is continually reoriented as the missile travels along its variable or controlled trajectory to the target. This is not to say that the launcher position on firing can be ignored. Most missile systems have correction and attitude control limits within which they must operate. The launcher must put the missile within these boundaries at launch or the missile's guidance system may not be able to compensate for the discrepancy.

MISSILE DIRECTION (GUIDANCE)

This phase consists of the acquisition of the target by the designated fire control system and the generation of the necessary missile control and guidance orders to intercept the target. Acquisition requires that a radar within the fire control system acquire and lock on to the target in order to gather information pertaining to target position and motion. This information is processed in the fire control computer to generate missile control and guidance orders. The missile control and guidance orders control the orientation of the missile trajectory needed to destroy the target. This information is sent to the launching system for proper positioning of the launcher and the missile it contains. The processing of target data and ballistic information factors is performed by analog or digital fire control computers.

Every missile guidance system consists of an attitude control system and a flight path control system. The attitude control system exercises control of the missile in roll, pitch, and yaw. It functions to maintain the missile in the desired attitude on the ordered flight path. The attitude control system of a missile operates essentially as an autopilot, damping out flight deviations that tend to deflect the missile from its ordered flight path. The function of the flight path control system is to determine the trajectory necessary for target interception and to generate the necessary orders for the attitude control system to follow.

Thus, the missile guidance system is essentially a fire control system and is inherently associated with the missile trajectory during the guidance phase. When a guided missile is employed, the missile trajectory decisions continue to be generated either within the missile during homing or by the fire control computer during remote guidance after the missile has been launched.

Many of the guidance systems discussed previously in this chapter may be combined to utilize the advantages of each system. For example, a surface-to-air missile may use preset guidance during the initial or launching phase to put the missile in the proper direction, command guidance during the midcourse phase, and homing guidance during the terminal phase.

PROBLEM SEQUENCE

We have already mentioned the sequence of operations that take place in the basic missile fire control problem. Let us plot these operations against a time base and compare their occurrence with the missile flight phases (fig. 3-35).

Detection operations are taking place during the period of time between T-1 and T-2. This period varies depending upon the complexity of an engagement and the operating conditions prevalent at the time. T-1 represents the time that target information is first disclosed. During detection the target's approximate position is established and initial target evaluation takes place. This evaluation includes considerations such as whether the target is hostile or friendly, and the degree of threat.

Designation occurs between T-2 and T-3. This represents the relatively short period of time that it takes to position the tracking radar to the approximate position of the target.

Acquisition, between T-3 and T-4, takes place after the tracking radar has accepted designation data from the data source (normally the NTDS/WDS). Due to the narrow beam of the fire control tracking radar, the tracking radar may not see the designated target. The tracking radar scans a volume of space around the designated point in space. This should result in acquisition of the target and cause the tracking radar's automatic tracking circuits to come into operation.

T-4 represents the time that automatic tracking starts. At this time, accurate target data is transmitted from the tracking radar to the fire control computer. Based upon this target data, the computer starts computing prediction and launch data. The prediction data is transmitted

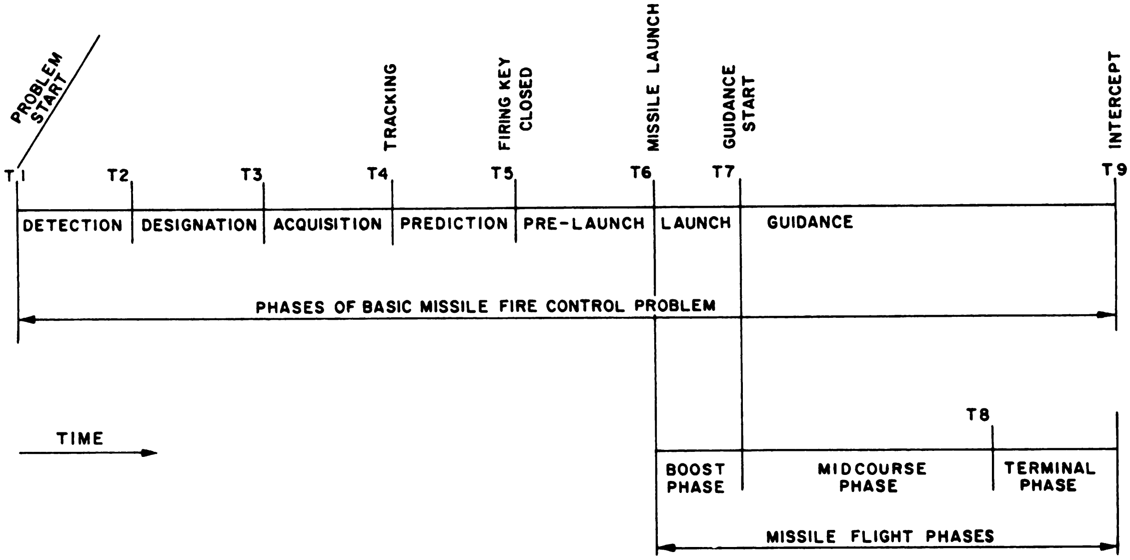


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Figure 3-35.—Problem sequence.

to the NTDS/WDS for a final evaluation of the target's engageability. Launch data computations provide launcher position data which is transmitted to the missile launcher when it is assigned to the appropriate fire control system.

Evaluation of a target's engageability continues until the determination has been made to fire. At this time, T-5, the firing key is closed. This initiates the prelaunch phase of operations. During prelaunch, the missile is brought to a flight operational status. The missile transmits "missile-ready-to-fire" to the NTDS/WDS when the missile firing circuits are completed and ignition of the missile booster squibs take place. This, in turn, ignites the missile booster and missile launch occurs at T-6. Prelaunch operations involve less than 2 seconds of time.

The launch phase of our problem corresponds to the boost phase of missile flight. During this period of time the missile is in flight and on its way to a point in space where the missile seeker head will slew toward and acquire the target. The missile will then be controlled by guidance signals, either from within or from an external source.

During launch the missile control surfaces may or may not be activated. If activated, they are striving to maintain missile stability during the boost phase. You can look at this as a form of missile guidance. However, for our problem, guidance is going to begin at T-7, shortly after booster burnout or separation. The time between T-6 and T-7 may vary from .5 second to between 4 to 7 seconds, depending on the missile. Guidance is in effect until intercept (T-9). The time duration of guidance, assuming a constant missile velocity, is dependent upon intercept range.

CHAPTER 4

MISSILE WEAPON SYSTEM TESTING AND SAFETY

You should now have some concept as to what a guided missile system is. Remember that a weapon system consists of many units of equipment which function individually and as units of the complete system. To ensure the accuracy and reliability of the weapon system, so that the ship can effectively engage an enemy, a series of tests have been developed. The tests, referred to as system tests, evaluate the ability of the weapon system to perform effectively. If the tests show that the system is not functioning properly, then corrective action is prescribed.

One of your primary responsibilities as a missile fire control technician will be weapon system testing. This chapter will familiarize you with what these tests consist of, how they are conducted, and their format.

As an FTM, you will also be responsible for safety. The equipment and materials with which you will work are, in many cases, hazardous. Their use requires strict adherence to safety requirements. This chapter discusses many of the precautions that you will use, including some of a general nature and some that are ordnance related.

Before getting into the main thrust of the chapter, however, let us briefly consider an overview of the Navy's overall approach to maintenance. The name of the Navy's total approach to maintenance is the Navy Ships' Maintenance and Material Management System (3-M Systems). The primary objective of the Ships' 3-M Systems is to provide for the managing of maintenance and maintenance support in a manner which will ensure maximum equipment operational readiness. The principal parts of the Ships' 3-M Systems are the Planned Maintenance System (PMS) and the Maintenance Data System (MDS). The objective of the Ships' 3-M Systems is attained through the effective use of PMS and MDS.

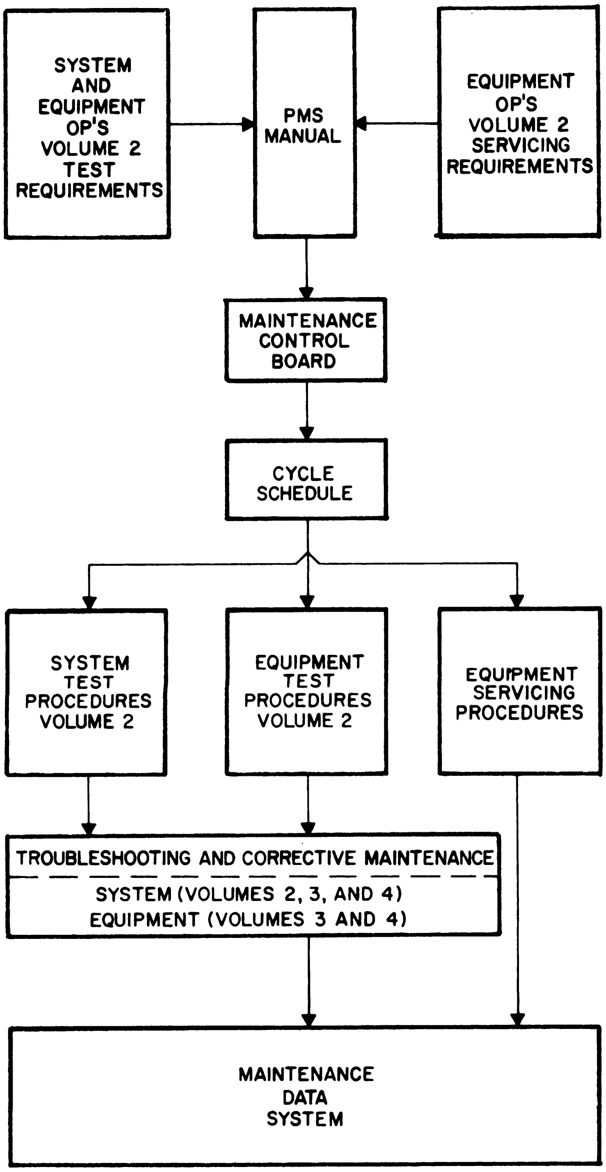
The Planned Maintenance System provides the ships with a program to ensure optimum system readiness. The Maintenance Data System facilitates effective reporting, collecting, processing, analysis, and distribution of maintenance data to enable line commanders and cognizant organizations to accomplish their respective functions in support of the operational forces.

The total requirements of the Ships' 3-M Systems are contained in an OPNAV instruction (OPNAVINST 4790.4). At this time, however, we are most concerned with shipboard requirements. This is due primarily to the fact that weapon system testing is a shipboard function and is a part of PMS.

PLANNED MAINTENANCE SYSTEM

Weapon system maintenance documentation has been developed for the Surface Missile Systems (SMS) as part of the Planned Maintenance System implemented by OPNAVINST 4790.4. This documentation, in conjunction with associated equipment ordnance publications or technical manuals (OPs/TMs) and the PMS manual, provides effective management of maintenance for surface missile systems. The management is based on the uniform execution of an integrated, system test oriented, preventive maintenance program.

Figure 4-1 illustrates the relationship of the PMS manual, the weapon system OP/TM, the associated equipment OPs/TMs, and the MDS. The PMS documentation is designed to enable maintenance personnel to accomplish essential testing and servicing in minimum time, and to rapidly diagnose and correct faults through a logical progression from testing and troubleshooting to the appropriate corrective maintenance. It is extremely important that maintenance personnel be familiar with PMS documentation.


SYSTEM AND EQUIPMENT OP'S VOLUME 2 TEST REQUIREMENTS
PMS MANUAL
EQUIPMENT OP'S VOLUME 2 SERVICING REQUIREMENTS
MAINTENANCE CONTROL BOARD
CYCLE SCHEDULE
SYSTEM TEST PROCEDURES VOLUME 2
EQUIPMENT TEST PROCEDURES VOLUME 2
EQUIPMENT SERVICING PROCEDURES
TROUBLESHOOTING AND CORRECTIVE MAINTENANCE
SYSTEM (VOLUMES 2, 3, AND 4)
EQUIPMENT (VOLUMES 3 AND 4)
MAINTENANCE DATA SYSTEM

167.869

Figure 4-1.—PMS maintenance documentation relationship.

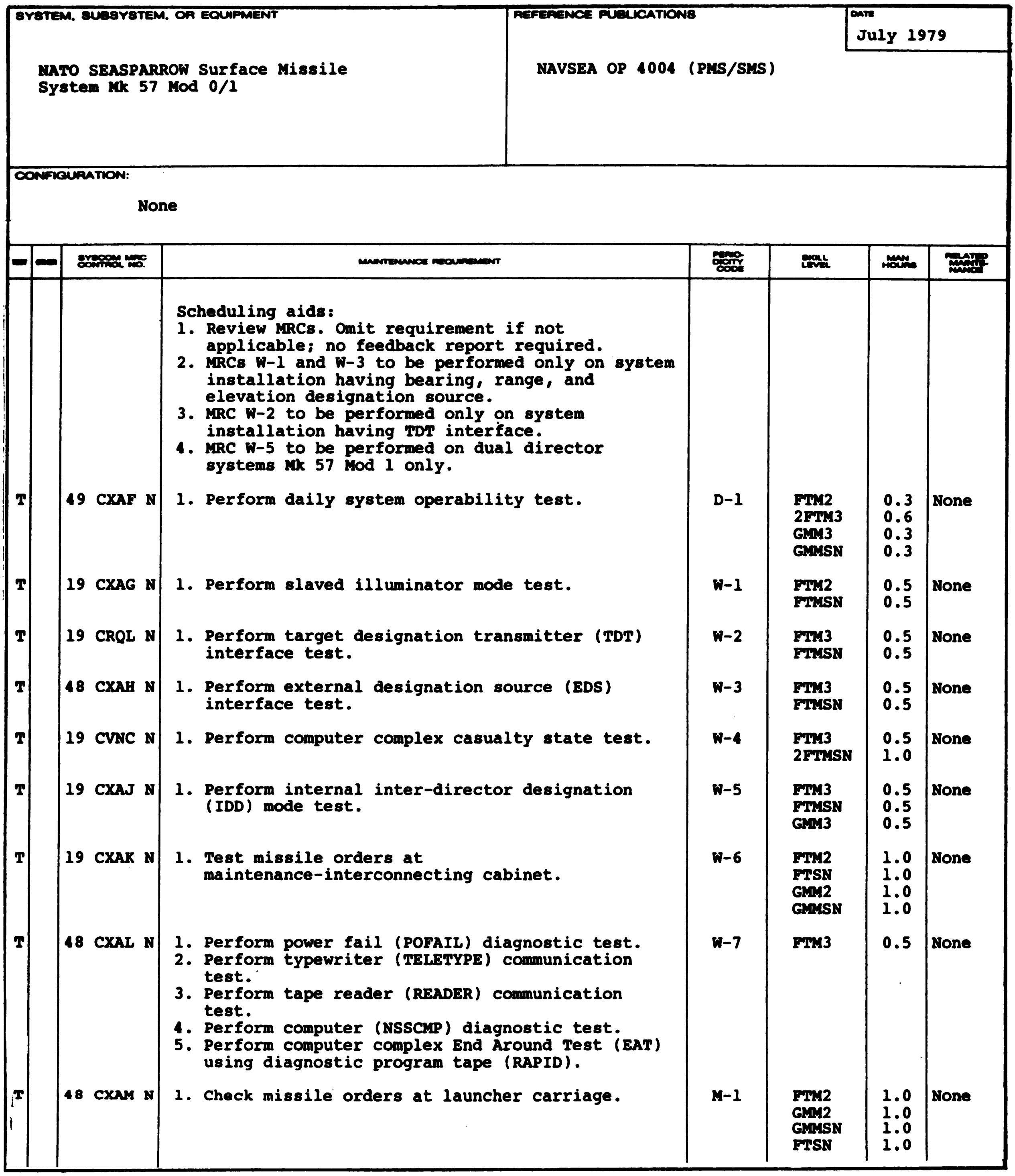
Some of the tools provided by PMS are Maintenance Index Pages (MIPs), maintenance schedules, and Maintenance Requirement Cards (MRCs). The Maintenance Data System, because of the way it supports maintenance, can also be looked upon as a tool of PMS.

More efficient planning and recordkeeping is accomplished through proper use of the MIPs, the maintenance schedules, and the MDS. Maintenance of complex equipment is reduced to simple procedures by providing technicians with MRCs. This chapter examines each tool individually.

Maintenance Index Pages are devised for equipment aboard a specific ship. Each MIP lists a set of MRCs for installed equipment. Also listed on each MIP is the title of each maintenance requirement, maintenance frequency code, rates of personnel required to perform the maintenance, man-hours, and related maintenance tests (fig. 4-2). The MIPs are contained in the PMS manual and are used for ready reference in conjunction with planning and scheduling maintenance.

Maintenance schedules enable supervisory personnel to effectively plan preventive maintenance actions. Proper use of maintenance schedules decreases downtime by substituting preventive maintenance for breakdown repair. Maintenance schedules used in PMS include the Cycle Schedule, the Quarterly Schedule, and the Weekly Schedule.

The Cycle Schedule displays the planned maintenance requirements to be performed between major overhauls of the ship. The Quarterly Schedule is a visual display of the PMS requirements to be performed by each work center of the ship during a specific 3-month period. The Weekly Schedule is a visual display of the planned maintenance scheduled for accomplishment in a given work center during a specific week. It is derived from the Quarterly Schedule. The Weekly Schedule is the one in which you should primarily be interested. It is the one that is referred to for daily work assignments.



SYSTEM, SUBSYSTEM, OR EQUIPMENT NATO SEASPARROW Surface Missile System Mk 57 Mod 0/1	REFERENCE PUBLICATIONS NAVSEA OP 4004 (PMS/SMS)	DATE July 1979
CONFIGURATION: None		

[illegible]	[illegible]	SYSCOM MRC CONTROL NO.	MAINTENANCE REQUIREMENT	PERIODICITY CODE	SKILL LEVEL	MAN HOURS	RELATED MAINTENANCE
			Scheduling aids: 1. Review MRCs. Omit requirement if not applicable; no feedback report required. 2. MRCs W-1 and W-3 to be performed only on system installation having bearing, range, and elevation designation source. 3. MRC W-2 to be performed only on system installation having TDT interface. 4. MRC W-5 to be performed on dual director systems Mk 57 Mod 1 only.				
T		49 CXAF N	1. Perform daily system operability test.	D-1	FTM2 2FTM3 GMM3 GMMSN	0.3 0.6 0.3 0.3	None
T		19 CXAG N	1. Perform slaved illuminator mode test.	W-1	FTM2 FTMSN	0.5 0.5	None
T		19 CRQL N	1. Perform target designation transmitter (TDT) interface test.	W-2	FTM3 FTMSN	0.5 0.5	None
T		48 CXAH N	1. Perform external designation source (EDS) interface test.	W-3	FTM3 FTMSN	0.5 0.5	None
T		19 CVNC N	1. Perform computer complex casualty state test.	W-4	FTM3 2FTMSN	0.5 1.0	None
T		19 CXAJ N	1. Perform internal inter-director designation (IDD) mode test.	W-5	FTM3 FTMSN GMM3	0.5 0.5 0.5	None
T		19 CXAK N	1. Test missile orders at maintenance-interconnecting cabinet.	W-6	FTM2 FTSN GMM2 GMMSN	1.0 1.0 1.0 1.0	None
T		48 CXAL N	1. Perform power fail (POFAIL) diagnostic test. 2. Perform typewriter (TELETYPE) communication test. 3. Perform tape reader (READER) communication test. 4. Perform computer (NSSCMP) diagnostic test. 5. Perform computer complex End Around Test (EAT) using diagnostic program tape (RAPID).	W-7	FTM3	0.5	None
T		48 CXAM N	1. Check missile orders at launcher carriage.	M-1	FTM2 GMM2 GMMSN FTSN	1.0 1.0 1.0 1.0	None

167.870

Figure 4-2.—A maintenance index page.

The Maintenance Data System provides a means of recording maintenance actions in substantial detail for easy retrieval and analysis. In addition, the system provides data concerning the initial discovery of the malfunction, the nature of the malfunction, the manhours expended, the equipment involved, the delays incurred, the reason for the delay, and the technical specialty or rating that performed the maintenance. As a result of the information received from the Maintenance Data System, design changes can be made, inventory requirements revised, and personnel requirements changed to increase the efficiency of the weapon system.

The Maintenance Requirement Cards define the preventive maintenance tasks, standardize maintenance procedures, list tools and materials needed during procedures, and state safety precautions that must be followed. A complete working set of equipment MRCs is located in a special container in each maintenance work center.

SYSTEM TESTING

System Maintenance Tests (SMTs), together with the associated equipment maintenance tests in the equipment OPs/TMs, provide a thorough check of the weapon system with minimum redundancy. All tests are scheduled at the minimum frequency necessary to ensure continued reliable performance of the system. Since an examination of all of the functional circuits of a weapon system by a single test is impractical, a test structure is provided that checks those parameters critical to the operation of the system.

Overall system testing is centered about the Daily System Operability Test (DSOT). This test is designed to exercise almost all of the functional circuits related to the primary mode of missile weapon system operation. Other system tests are provided for those functional circuits not covered by the DSOT. These include, but are not limited to, tests designed to accomplish the following:

- Check other system operational modes
- Verify the optical and rf alignment between various elements of the system
- Check operation against a live target

System test results can be determined by system response and parameter tolerances provided by indicators such as lamps, dials, meters, computer printouts, and through careful analysis of other recorded data. The test results provide the "yardstick" for measuring the success or failure of the tests.

Equipment tests check those circuits not checked by system tests. Equipment testing and servicing procedures are provided in the equipment OPs/TMs and on Maintenance Requirement Cards.

TROUBLESHOOTING DOCUMENTATION

Documentation, both at the system level and at the equipment level, has been developed to provide a systematic procedure of troubleshooting. At the systems level, are such things as a System Indicator Fault Directory, a Test Fault Directory, Fault Logic Diagrams (FLDs), and System Functional Diagrams (SFDs). At the equipment level, are such things as a Maintenance Turn-on Procedure, a Troubleshooting Index, a Relay and Lamp Index, Signal Flow Diagrams, Relay Ladder Diagrams, and Power Distribution Diagrams. All of these documents are designed to facilitate troubleshooting procedures.

At this time, it is not necessary for you to have a detailed knowledge of troubleshooting documentation. You should, however, be aware that such documentation exists and that the various procedures/diagrams lead to the alignment and adjustment of malfunctioning systems and the repair and replacement of faulty components. Figure 4-3 illustrates the relationship between system and equipment troubleshooting documentation.

Indications of a failure noted during system/equipment tests or operation are used to

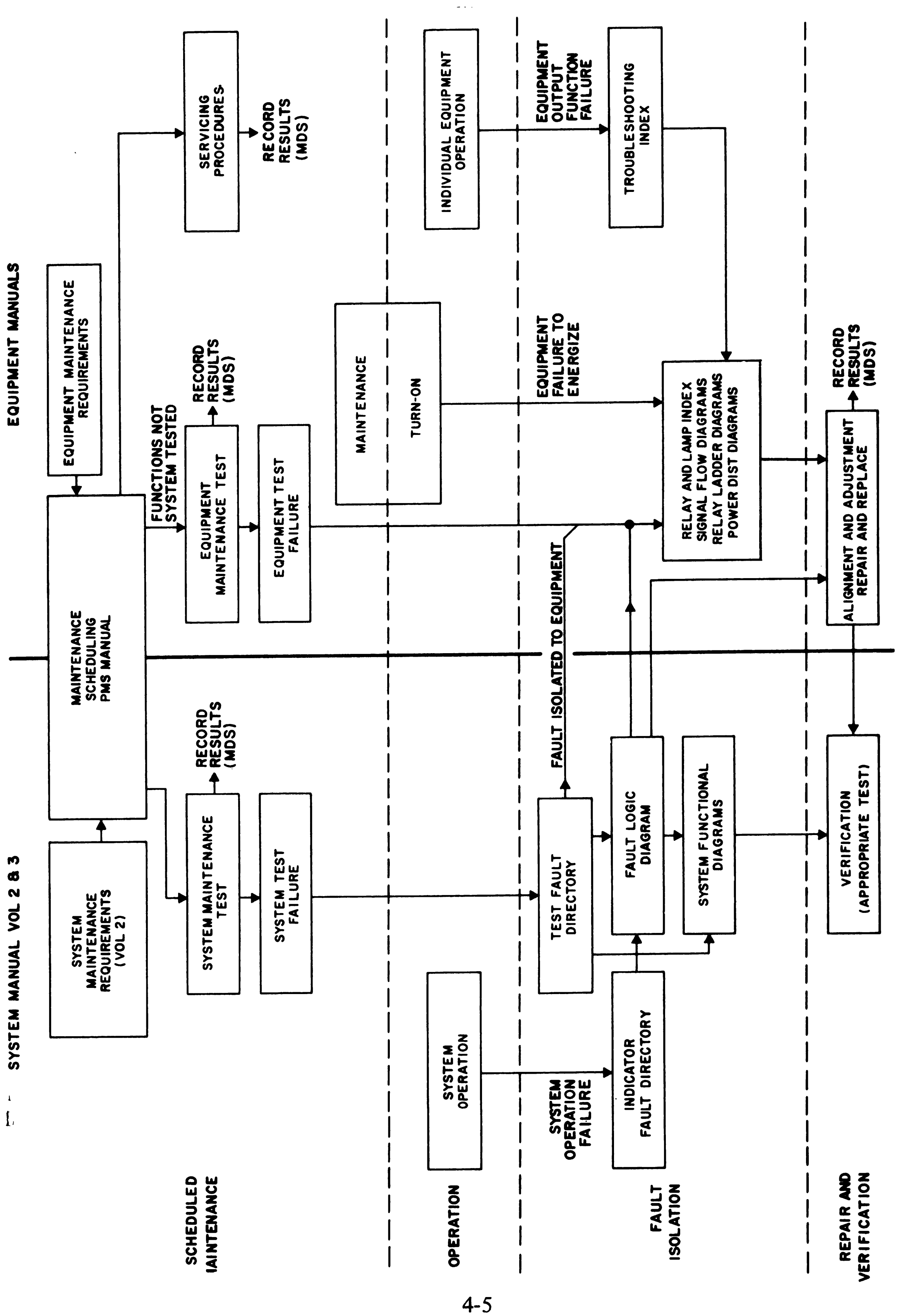


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Figure 4-3.—PMS/SMS maintenance documentation.

make reference to (entry into) the most appropriate troubleshooting documentation. For system test failures, entry is accomplished by the Test Fault Directory. Provision is also provided, however, for failures noted during system operation, failures noted during equipment turn-on, and failures noted during individual equipment operation. Let us look at the systems level documentation and the equipment level documentation separately.

System Troubleshooting Documents

The systems of the surface missile system fleet are varied. As a result, they sometimes have varying types of documentation. In general, however, the system documentation seen in the fleet is similar to that described in this text. Even where different, the information provided herein can be related to all existing formats. The techniques of troubleshooting do not vary.

The system test-related troubleshooting references, FLDs/SFD, (and sometimes equipment troubleshooting procedures) are provided with each test for which the results are directly evident. As we have indicated, this is accomplished by the Test Fault Directory. For each fault indication listed, a direct reference is made to the most appropriate troubleshooting procedure (FLD) and/or diagram (SFD).

The system Indicator Fault Directory (fig. 4-4) references the appropriate SFD required to troubleshoot a fault that is disclosed by an incorrect indication during normal operation or system exercise. This directory is an alphabetical listing of all the indicators shown in the SFDs, with references to the diagrams associated with each indicator.

A Fault Logic Diagram (FLD) is used to speed troubleshooting by requiring the technician to answer a series of branching questions about an observed system fault (fig. 4-5). The questions, which permit only "yes" or "no" answers, pertain primarily to the status of

Indicator Fault Directory

EQUIPMENT/INDICATOR	FLD'S		SFD'S	
	PART	FIGURE	PART	FIGURE
RADAR CONSOLE (Cont)				
SURFACE TRACK Lamp			4	11-1.22
(GREEN/YELLOW)			7	11-2.22
TDT DESIG Lamp			3	11-1.13
			6	11-2.13
TELEVISION ON Lamp			5	11-1.40
			8	11-2.40
TELEVISION OFF Lamp			5	11-1.40
			8	11-2.40
TRACK ALARM Lamp	1	10-2.10	4	11-1.22
	1	10-2.10	7	11-2.22
WDE DESIG Lamp	1	10-2.5	3	11-1.13
	1	10-2.5	6	11-2.13
1X MAGNIFICATION Lamp			5	11-1.40
			8	11-2.40
5X MAGNIFICATION Lamp			5	11-1.40
			8	11-2.40

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Figure 4-4.—Indicator Fault Directory.

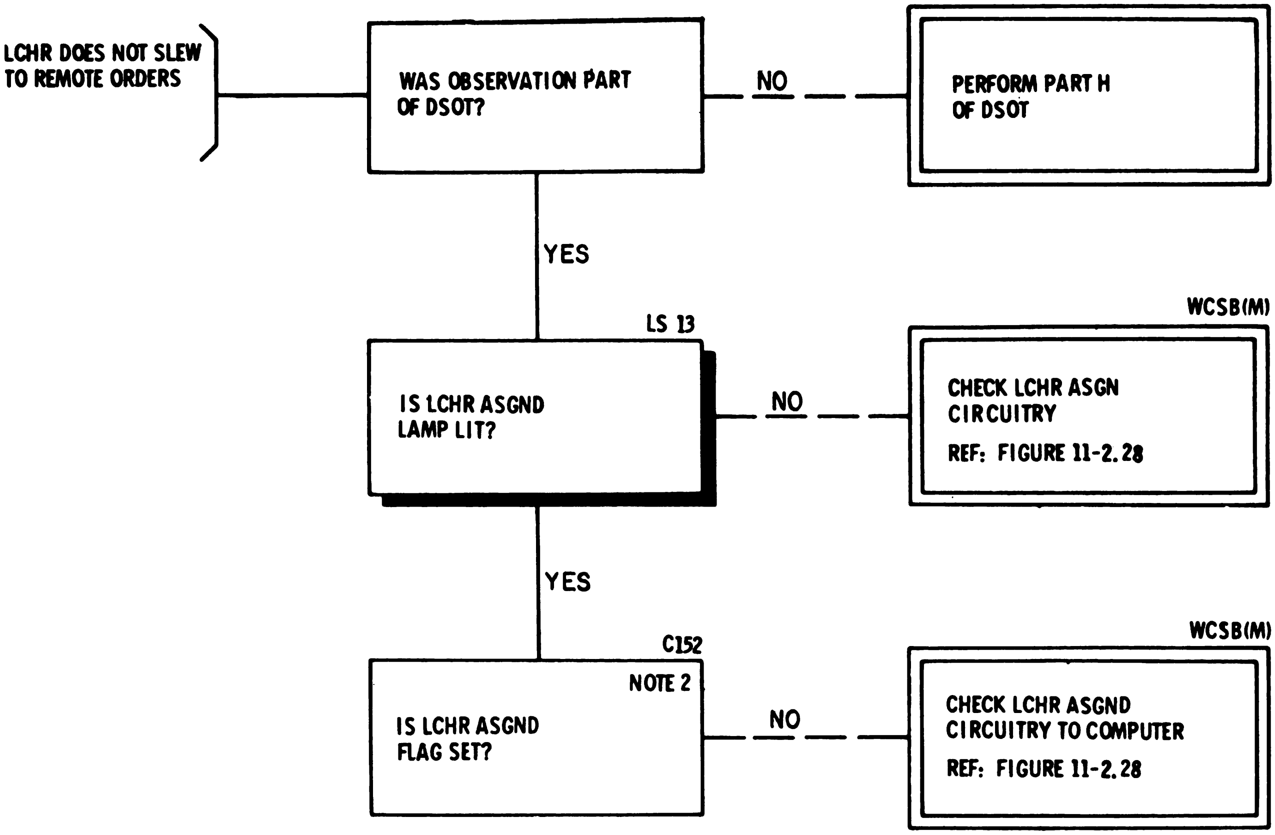

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Figure 4-5.—Fault Logic Diagram.

external indications (lamps, dials, meters, scope displays, etc.). They may also pertain to internal indications provided at key test points. By a process of elimination, the technician is led to the area of probable trouble and is referred to appropriate equipment troubleshooting documents.

A System Functional Diagram (SFD) is a functional flow diagram that serves as a system study, analysis, and troubleshooting tool (fig. 4-6). An SFD contains all the circuits necessary for a functional understanding of a particular mode or phase of system operation.

Equipment Troubleshooting Documents

As with system documentation, equipment documentation is slightly diverse. Different manufacturers build different parts of a weapons system. The various units of equipment sometimes have different design concepts. Therefore, each may be provided with slightly different types of troubleshooting documents. Overall, however, they are as we have described in this chapter.

Equipment OPs/TMs contain the documentation that enables rapid localization of faults that have been traced to a particular piece of equipment. A troubleshooting index lists all output functions of the equipment and applicable references. In addition, turn-on procedures are provided for energizing the equipment. These procedures contain references to troubleshooting documents that are to be used if a given step of the procedure cannot be performed satisfactorily. Included in these documents are the Relay and Lamp Indexes,

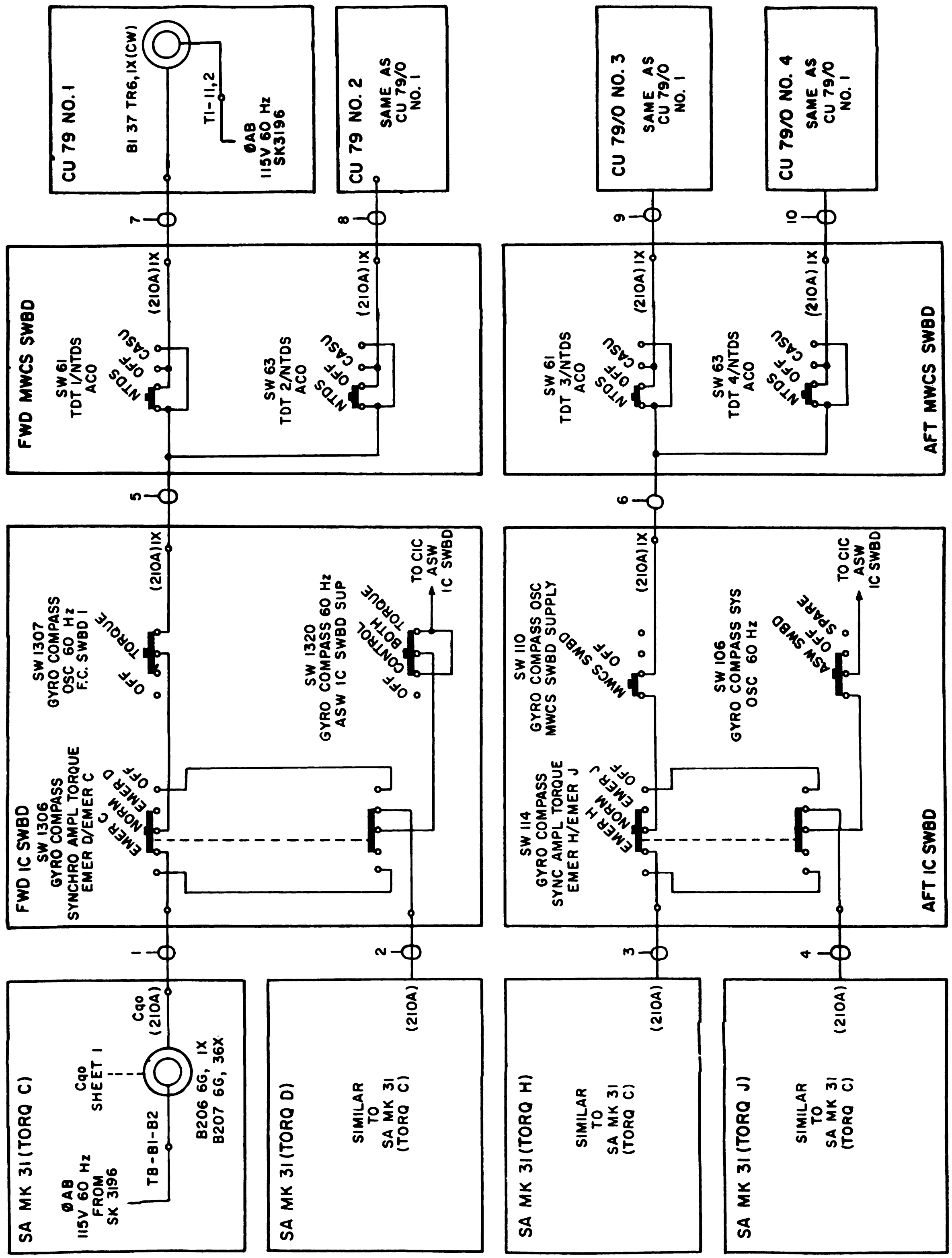

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Figure 4-6.—Sample System Functional Diagram.

Signal Flow Diagrams, Relay Ladder Diagrams, and Power Distribution Diagrams.

We have purposely not said much about equipment documents because they are covered in greater detail in a later chapter.

WEAPON SYSTEM TESTING REQUIREMENTS

The missile system must be maintained in an optimum state of readiness to ensure a successful target engagement. Optimum readiness is achieved by system and equipment level PMS/SMS tests.

Surface missile systems may have different functional modes of operation. The normal mode is usually antiair warfare (AAW). Antiship missile defense (ASMD), surface warfare (SUW), and shore modes are optional. There may also be a casualty mode to allow for operation when parts of the weapon system are inoperable. (The HARPOON system is unique in that its only mode is surface (SUW) and its operability test is not needed on a daily basis.)

Each mode of a particular system is examined to determine the requirements necessary to ensure reliable performance. In each mode of operation, the requirements are grouped into two major areas–alignment requirements and electrical operability requirements.

Alignment requirements are divided into two separate groups: in-space rf (or optical) alignments and internal (shipboard) alignments. In-space rf alignment requires that rf beams of the fire control, search, and guidance radars be coincident. The internal or shipboard alignments include those mechanical and electrical alignments required for reliable system operation that are not in-space related. Alignment procedures are provided that correct misalignments in either group. However, they are not performed on a scheduled basis but only as required by faulty test results.

Electrical operability requires that all switching, control, and indicator functions be operable.

WEAPON SYSTEM TEST COVERAGE

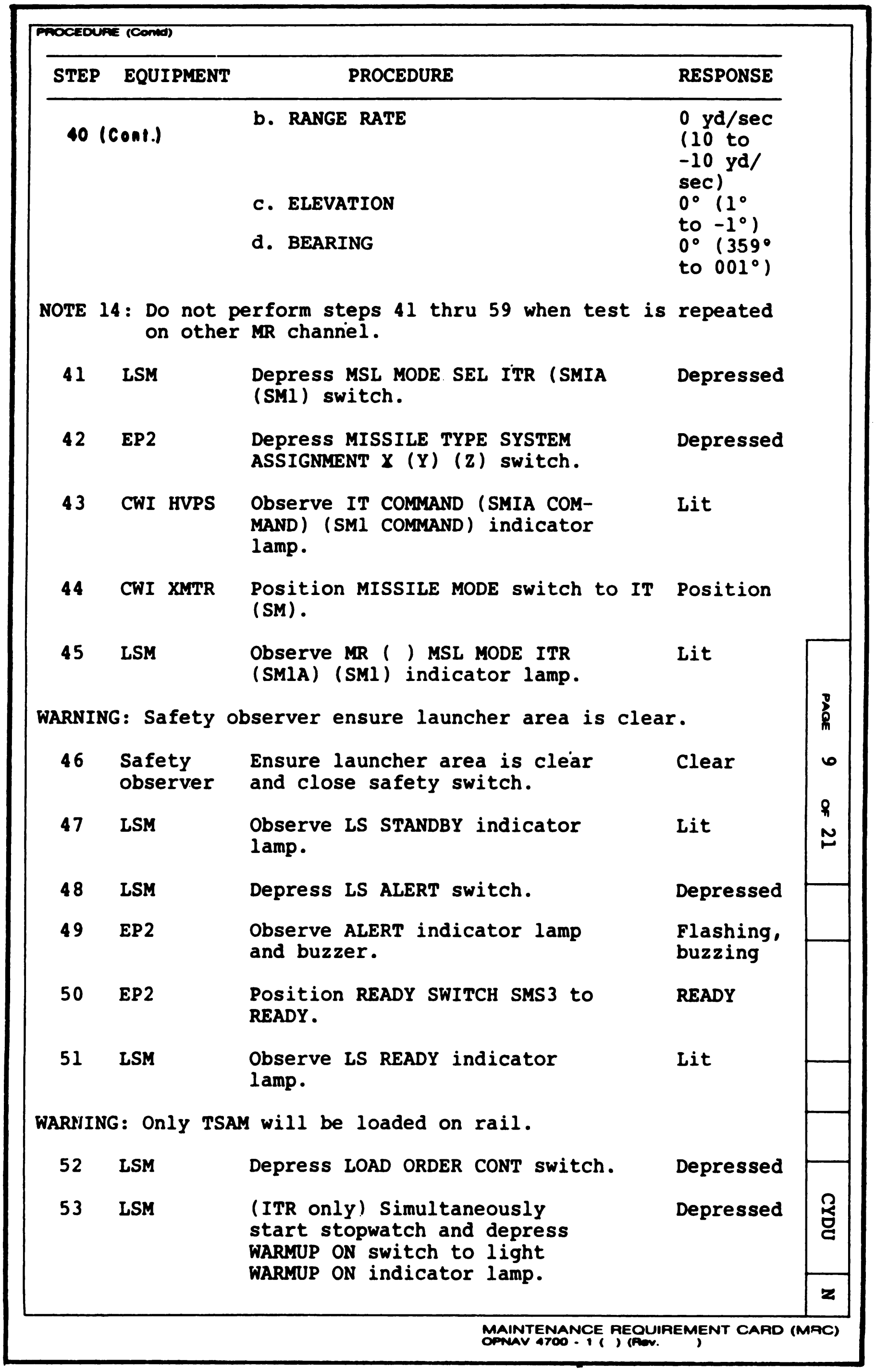
Each test is letter-coded according to the required periodicity (frequency of test application or period between tests). Thus, the following letters are individually prefixed to a test number to assist scheduling: D for daily, W for weekly, M for monthly, Q for quarterly, or R for as required. For certain systems, weekly tests are designed to test separately identified equipment combinations, setups, and modes. This concept requires that these weekly tests be scheduled over a 6-day period and actually make up the daily system operability test. Periodicity is established by determining the importance and reliability of the circuits to be checked.

A typical missile system test listing might include but not be limited to the following:

- Daily System Operability Test
- Search radar readiness
- Supplemental firing readiness
- Casualty mode operation
- Ship parameters (gyro inputs)
- Radar Collimation/correlation
- ECCM capabilities
- Fire control radar parameters
- Live target tracking (AAW)
- Balloon tracking (desig. accuracy)
- Surface target tracking

WEAPON SYSTEM TEST PROCEDURE

The test procedures are presented in a step-by-step format to provide maximum efficiency of the test performance. This arrangement permits one test conductor to control and direct test personnel while continually monitoring system status. Since a



PROCEDURE (Contd)

STEP	EQUIPMENT	PROCEDURE	RESPONSE
40 (Cont.)		b. RANGE RATE	0 yd/sec (10 to -10 yd/sec)
		c. ELEVATION	0° (1° to -1°)
		d. BEARING	0° (359° to 001°)

NOTE 14: Do not perform steps 41 thru 59 when test is repeated on other MR channel.

STEP	EQUIPMENT	PROCEDURE	RESPONSE
41	LSM	Depress MSL MODE SEL ITR (SMIA (SM1) switch.	Depressed
42	EP2	Depress MISSILE TYPE SYSTEM ASSIGNMENT X (Y) (Z) switch.	Depressed
43	CWI HVPS	Observe IT COMMAND (SMIA COMMAND) (SM1 COMMAND) indicator lamp.	Lit
44	CWI XMTR	Position MISSILE MODE switch to IT (SM).	Position
45	LSM	Observe MR ( ) MSL MODE ITR (SM1A) (SM1) indicator lamp.	Lit

WARNING: Safety observer ensure launcher area is clear.

STEP	EQUIPMENT	PROCEDURE	RESPONSE
46	Safety observer	Ensure launcher area is clear and close safety switch.	Clear
47	LSM	Observe LS STANDBY indicator lamp.	Lit
48	LSM	Depress LS ALERT switch.	Depressed
49	EP2	Observe ALERT indicator lamp and buzzer.	Flashing, buzzing
50	EP2	Position READY SWITCH SMS3 to READY.	READY
51	LSM	Observe LS READY indicator lamp.	Lit

WARNING: Only TSAM will be loaded on rail.

STEP	EQUIPMENT	PROCEDURE	RESPONSE
52	LSM	Depress LOAD ORDER CONT switch.	Depressed
53	LSM	(ITR only) Simultaneously start stopwatch and depress WARMUP ON switch to light WARMUP ON indicator lamp.	Depressed

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MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4700 - 1 ( ) (Rev.)

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Figure 4-7.—Sample system test MRC.

test requires many stations to participate simultaneously, each test procedure contains a response column to enable the test conductor to control test performance. During the test, the test conductor calls out step numbers in sequence, receives the appropriate response from the associated station for each step, and records all data to minimize record keeping. Figure 4-7 is a sample MRC showing procedures of various stations.

Each test is divided into independent phases where possible. This arrangement helps both fault isolation and testing because a particular part or parts of the system may be checked without conducting an entire test.

Error Evaluation

Selected parameters from the weapon system under test are sampled or measured to specified tolerances. These tolerances, along with the desired response, are listed on the MRC card following the applicable step. (See step #40 in the sample of fig. 4-7.)

Fault Isolation

Fault isolation directories for each test are located in the MRCs and are keyed to corresponding steps of the test procedures (fig. 4-8). If an out-of-tolerance condition or undesired response is observed, information in a fault isolation procedure or isolation reference (SFD) can be used to find the cause of the problem or, at least, to isolate the discrepancy to a particular piece of equipment in the system. Equipment OPs may also be referenced.

It is, however, recommended that the test conductor proceed completely through a test without pausing for fault isolation of any kind, unless one of the major system elements is so disabled as to prevent continuation. Completing the test permits the test conductor to evaluate the tests more accurately to determine all areas where maintenance is required. It also results in the most efficient use of manpower.

Digital System Testing

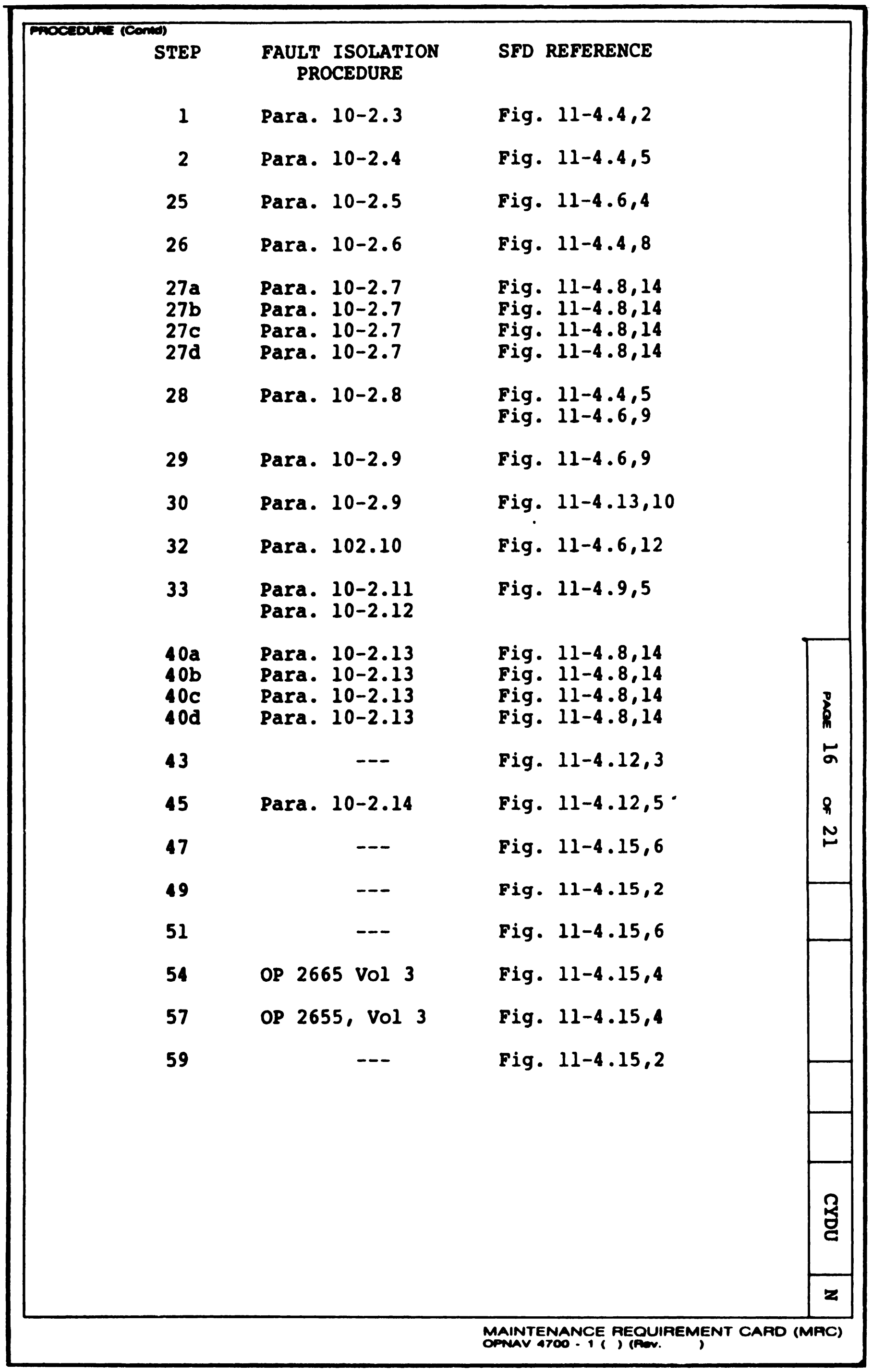
A significant feature of the digital fire control system is the use of a general-purpose digital computer in place of a conventional analog fire control computer. Thus, the fire control problem is solved by a digital computer tactical program instead of a hardwired electromechanical device. Digital test programs have been designed to test a system by using the digital computer and its peripheral equipment to interface with other equipment of the fire control system.

Dynamic digital tests utilize the digital complex of the FCS or the NTDS/WDS (Naval Tactical Data System/Weapons Direction System) to control the tests. A digital computer with a special test program in storage generates a variety of dynamic synthetic targets. The test program solves the fire control problem to arrive at ideal values, and compares these values with the actual tracking solution, thus providing error monitoring. Teletypewriters can be used to print out the errors for evaluation and to provide a record of test results.

A new concept in digital testing uses computer controlled fault detection and isolation. This can be done concurrently or alternately with normal computer operations.

DAILY SYSTEM OPERABILITY TEST

The purpose of DSOT is to assess missile system readiness in its normal mode of operation. For most systems, this would be the AAW mode. Although the specific functions tested may vary between systems, DSOT usually involves testing target detection and/or designation, acquisition, tracking, and missile firing. A typical DSOT is described in the



PROCEDURE (Cont'd)

STEP	FAULT ISOLATION PROCEDURE	SFD REFERENCE
1	Para. 10-2.3	Fig. 11-4.4,2
2	Para. 10-2.4	Fig. 11-4.4,5
25	Para. 10-2.5	Fig. 11-4.6,4
26	Para. 10-2.6	Fig. 11-4.4,8
27a	Para. 10-2.7	Fig. 11-4.8,14
27b	Para. 10-2.7	Fig. 11-4.8,14
27c	Para. 10-2.7	Fig. 11-4.8,14
27d	Para. 10-2.7	Fig. 11-4.8,14
28	Para. 10-2.8	Fig. 11-4.4,5 Fig. 11-4.6,9
29	Para. 10-2.9	Fig. 11-4.6,9
30	Para. 10-2.9	Fig. 11-4.13,10
32	Para. 102.10	Fig. 11-4.6,12
33	Para. 10-2.11 Para. 10-2.12	Fig. 11-4.9,5
40a	Para. 10-2.13	Fig. 11-4.8,14
40b	Para. 10-2.13	Fig. 11-4.8,14
40c	Para. 10-2.13	Fig. 11-4.8,14
40d	Para. 10-2.13	Fig. 11-4.8,14
43	---	Fig. 11-4.12,3
45	Para. 10-2.14	Fig. 11-4.12,5
47	---	Fig. 11-4.15,6
49	---	Fig. 11-4.15,2
51	---	Fig. 11-4.15,6
54	OP 2665 Vol 3	Fig. 11-4.15,4
57	OP 2655, Vol 3	Fig. 11-4.15,4
59	---	Fig. 11-4.15,2

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MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4700 - 1 ( ) (Rev.)

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Figure 4-8.—Sample Test Fault Directory.

following paragraphs. Figure 4-9 is a simplified block diagram of DSOT data flow.

Preliminary Setup

Prior to starting the test sequence, each equipment space prepares for operation guided by a list of instructions preliminary to the test procedure. Most setups involve switch positioning and equipment turn-on procedures. In some cases, the test conductor also announces a particular equipment configuration.

Detection

In systems that test this function, a synthetic target video is inserted in the 3-D search radar at a predetermined range, bearing, and elevation. After routing through the normal distribution circuits, the target video is checked at the NTDS/WDS display consoles. The test target is then entered into a WDS tracking circuit.

FCS Assignment

If the detection function is not tested, a WDS or NTDS/WDS operator initiates a test target at an FCS assignment console. Then the missile fire control system (MFCS) is assigned to the WDS tracking channel. Accuracy of the designated position is checked at the fire control director or radar console and, if applicable, execution of a search pattern is verified. FCS position repeat back is checked at the NTDS/WDS.

Acquisition and Static Track

A test rf generator provides the fire control radar with a simulated target return signal. Radar jamming signals may also be provided. The radar's scope display is monitored to see how well the radar can acquire the target. How much of the radar receiver is tested is determined by where the test signal is introduced. The test signal contains information needed for radar tracking, including angle error and range. Target parameters are usually controlled by a test program, as previously mentioned, located in the NTDS/WDS or FCS

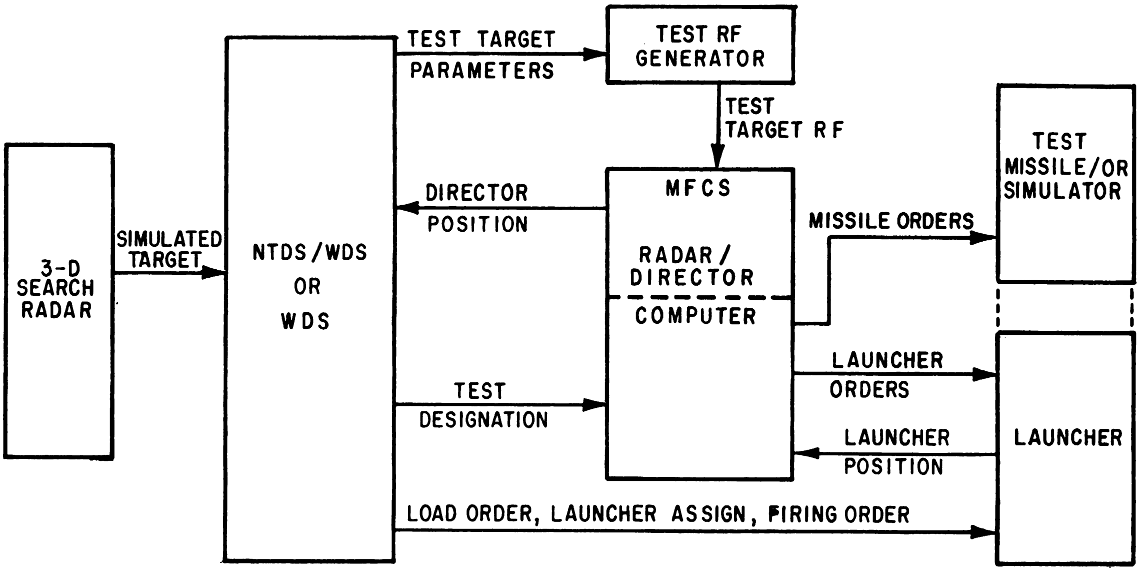

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Figure 4-9.—Simplified DSOT data flow.

software (programming). Control is also possible from an analog test set.

Launcher Loading and Missile Selection

After track is attained, if a training missile is to be used, the launcher goes through a loading sequence. IT IS OF EXTREME IMPORTANCE THAT ONLY A TEST MISSILE IS LOADED AND VERIFIED. Otherwise, the test would result in the actual launching of a live missile.

Missile type and mode selection might also be tested at this time. The test missile or simulator provides these functions.

Dynamic Evaluation

During this phase of DSOT, two aspects of system operation are tested. The first is the FCS tracking of a dynamic target. The second is launcher assignment and synchronization to a computer ordered position.

Target parameters are selected that simulate an incoming enemy aircraft. The fire control system is monitored to ensure smooth and accurate tracking. The launcher is assigned and the fire control problem solution is verified by monitoring launcher and missile orders and by observing engageability displays at the weapon control area (NTDS/WDS).

When displays at the NTDS/WDS indicate that the target is within firing range and the launcher is at a clear firing bearing, the firing circuit is closed. A proper firing indication is monitored at the launcher station, and then the launcher operator initiates a simulated missile-in-flight indication, which is verified at various weapon stations.

Test Missile Readouts

Certain signals are essential to missile operation, but may not be automatically checked. Visual observations, by means of built-in lamps and dials, are made at the test missile or missile simulator. Signals, such as missile orders, are sometimes checked with a voltmeter. A serious safety hazard exists when making measurements or otherwise approaching the missile while it is on the launcher. ALWAYS ENSURE THAT ALL LAUNCHER MOTORS ARE STOPPED BEFORE APPROACHING.

OCSOT

Another test you may be involved with is the Overall Combat System Operability Test (OCSOT). The OCSOT provides the ship's commanding officer with a tool to make a rapid assessment of the readiness of the entire combat system. It tests the combat system as an integrated system using normal equipment, software, and interfaces during both simulated and controlled live target phases. As a rule, the following systems are tested:

- Guided missile fire control
- Gun fire control
- Antisubmarine warfare
- Electronic warfare
- Tactical data
- Identification friend or foe (IFF)
- Search radars
- Electronic navigation

The OCSOT has specified parameters such as range, bearing, and elevation tolerances for all phases, as well as proper reaction times for systems and operators. As an added benefit, the OCSOT results in training for improvement of operational readiness in a combat environment.

WEAPON SYSTEM ALIGNMENT

Alignment related to the weapon system is discussed briefly in this section. You may at times hear this referred to as battery alignment. The objective is to align the elements of the weapon system to common references. These alignments are essential to ensure that all data transferred between weapon system elements are useful and accurate.

Initial alignment is established by the shipbuilder or overhaul yard using methods and specifications contained in a shipyard weapon system alignment manual.

TYPES OF ALIGNMENT

System alignment may be divided into two separate types—the internal alignment of an equipment or element, and the alignment of the elements to each other. Initial responsibility for element internal alignment rests largely with the manufacturer and is rechecked during installation and scheduled shipboard tests. The alignment of the elements to each other as they function in a weapon system can, in turn, be subdivided into two categories, mechanical and electrical alignment. Mechanical alignment, which always precedes electrical alignment, refers to establishing effectively parallel mountings; electrical alignment refers to the accuracy of data transmission between the elements.

MECHANICAL ALIGNMENT

System elements are mechanically aligned when their projected lines of sight are parallel and their associated indicators are in agreement with a common angular displacement from the fire control reference plane. Since mechanical alignment is extremely critical to weapon system accuracy, the tolerances for alignment of mechanical foundations are listed in the detailed ship class specifications, and are repeated in the shipyard alignment manual.

Bench marks (fig. 4-10) are installed to aid in verifying the mechanical alignment. The bench mark is a small metal plate containing an engraved cross. It is welded to some rigid part of the ship structure where it can be sighted on by an equipment. Dial readings are taken and recorded during initial shipyard alignment and

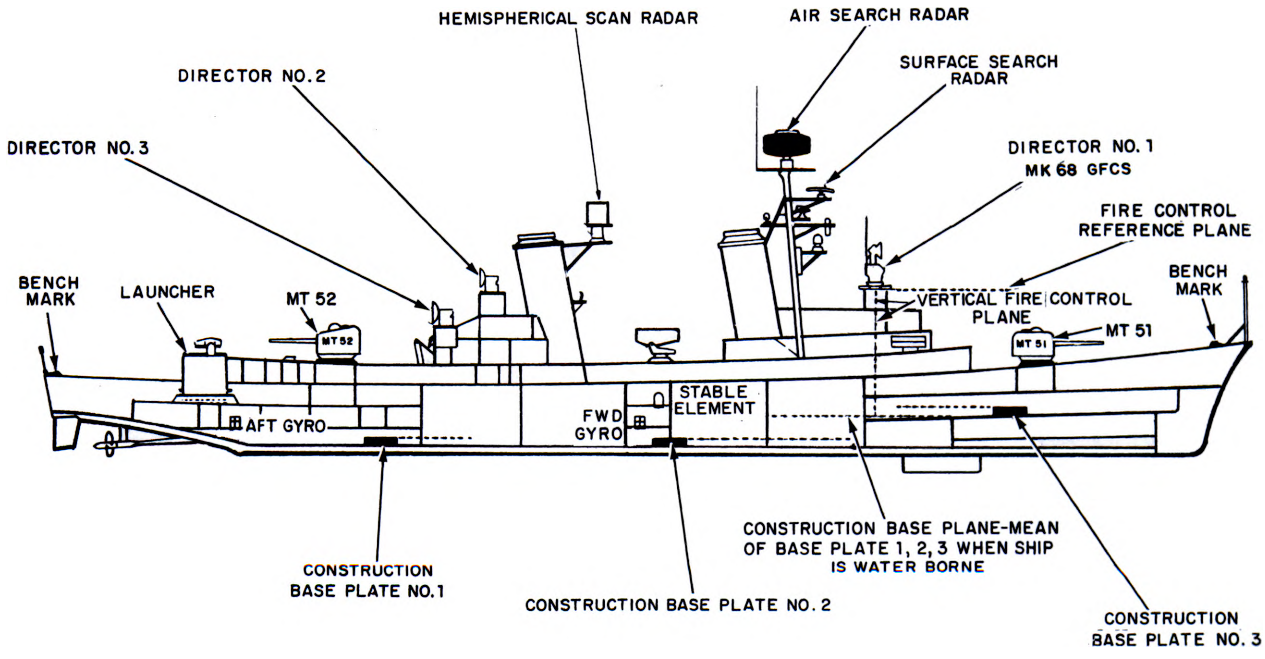
HEMISPHERICAL SCAN RADAR
AIR SEARCH RADAR
DIRECTOR NO. 2
SURFACE SEARCH RADAR
DIRECTOR NO. 3
DIRECTOR NO. 1 MK 68 GFCS
FIRE CONTROL REFERENCE PLANE
BENCH MARK
LAUNCHER
MT 52
MT 52
BENCH MARK
VERTICAL FIRE CONTROL PLANE
MT 51
MT 51
STABLE ELEMENT
FWD GYRO
AFT GYRO
CONSTRUCTION BASE PLANE-MEAN OF BASE PLATE 1, 2, 3 WHEN SHIP IS WATER BORNE
CONSTRUCTION BASE PLATE NO. 1
CONSTRUCTION BASE PLATE NO. 2
CONSTRUCTION BASE PLATE NO. 3

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Figure 4-10.—Mechanical alignment elements.

are used as a reference for future shipboard verification.

Construction Base Plane

During the ship's construction, one or more construction base plates are installed within the ship's hull (fig. 4-10). These plates, referenced to a similar plate mounted on a fixed ground installation, are accurately leveled, using the most advanced techniques and instrumentation available, before the ship is launched. Due to hull distortion after launching, the construction base plates may no longer be level and any errors attributed to this distortion must be corrected. The correction is made by taking comparative readings at the construction base plates, averaging the errors, and establishing a construction base plane. This is an imaginary plane based upon the construction base plates, and it is used as the reference to which the foundation of the reference element (in this example, Director Mk 68) is machined.

Fire Control Reference Plane

The foundation of the reference element is machined parallel to the construction base plane and serves as the fire control reference plane. This is the reference to which all system elements are aligned. All major element foundations (launcher, director, and gun mounts) are machined parallel to the fire control reference plane.

After the fire control reference plane is established, a vertical plane perpendicular to the fire control reference plane and lying along, or parallel to, the ship centerline is established. This plane is the zero train reference for all system elements.

ELECTRICAL ALIGNMENT

The system is electrically aligned when the transmitting equipment in each element electrically represents the angular relationship of that element to the fire control reference plane and the ship centerline. Receivers must be aligned to their respective references, accounting for associated transmission line losses. Classical battery alignment places major emphasis on the physical relationship of planes and dials.

ALIGNMENT AFLOAT

Ship's force is responsible for periodically verifying alignment during operational periods and for maintaining the initial state of alignment. The system maintenance tests provide the necessary verification. Corrective maintenance is contained in the system OPs.

SAFETY

Your duties as a missile fire control technician will require constant attention to the observance of safety precautions. These safety precautions include those concerning work done on or with electrical and electronic equipment, work involving the handling of explosive ordnance material, work in the vicinity of equipment capable of starting fires or generating toxic gases, work done on high-pressure hydraulic and pneumatic systems, and work done with small power tools.

In this chapter, safety is looked at in terms of ordnance and fire control system operation. Safety related to fire control radars and their maintenance is detailed in chapter 5, Fire Control Radars.

General safety precautions and basic first-aid treatment relating to electricity, electronics, and handtools are discussed in chapter 8, General Maintenance.

Because of the many specialized devices you use and because of the potential hazards in your work, you should consider the formation of safe and intelligent work habits as being equal in importance to the development of technical knowledge and skills. You should always strive to exhibit the attitudes and practices which are characteristic of "safety-mindedness." One of your objectives should be to become a safety specialist, trained in recognizing and correcting dangerous conditions and in avoiding unsafe actions. As a Petty Officer, you will be obligated, and expected, to pass on to your junior personnel the safety knowledge and experience you have acquired through your own training and to demonstrate good safety habits.

Each missile fire control technician is expected to observe all of the safety precautions set forth in local directives, in equipment maintenance manuals, and in Naval Sea Systems Command Ordnance Publications (OPs) and Ordnance Data (ODs).

SAFETY PHILOSOPHY

In a study of safety precautions, it is difficult to cover every possible situation that may arise and which, if improperly handled, may produce serious result. However, if a thorough understanding of the basic ideas behind the precautions is developed, unsafe conditions can be recognized and corrected, and suitable action can be taken instinctively when the unexpected occurs.

Some actions and attitudes which are to be carefully avoided are carelessness, noncompliance with procedures, lack of alertness, disorganized haste, ignorance, and overconfidence in the performance of your duties.

In addition to system manuals and publications which contain safety precautions applicable to a specific system, you will find other OPs in the weapons library covering general ordnance safety.

GENERAL SAFETY PRECAUTIONS

Even though the guided missile and the missile fire control equipment is complex in operation and uses propellants and explosives, the handling and testing of these are relatively safe when the proper equipment and procedures are used.

All operations should be performed carefully, methodically, and without hurrying. Greater effectiveness in the assembly and launching of the missile will be developed as you become increasingly familiar with your assigned duties. During any missile handling operation, if a malfunction occurs or an incorrect indication appears, STOP the operation immediately and determine whether or not it is safe to proceed. Before performing any step in a procedure, be sure that the preceding step has been properly executed and the correct results obtained.

Cleanliness and good housekeeping in all working areas are major factors in effective accident prevention. Tools and equipment should be maintained in good working order and should always be returned to their proper storage places after use.

Safety devices found on mechanical or electrical systems are put there for your protection and the protection of the equipment. These devices must be maintained in good order and operative at all times. You should never remove safety devices or bypass them unless specifically authorized. Where safety devices have been rendered inoperable by proper and specific authorization, adequate notices must be posted to warn personnel of the potential hazard.

Avoid the use of flammable or toxic cleaning fluids such as gasoline, benzine, ether, and alcohol. The use of carbon tetrachloride is prohibited.

PNEUMATIC AND HYDRAULIC SAFETY

Hydraulic systems operate under hydraulic pressures ranging from approximately 100 psi to 2,000 psi. Some pneumatic systems operate in approximately the same range of pressures as hydraulics. These pressures are dangerous and can be hazardous to personnel.

Safety precautions must be observed when performing maintenance, testing, and operating ordnance hydraulic and pneumatic equipment. The high-pressure liquid or air can cause major injuries to the face, the hands, and other parts of the body by jets of air or liquid escaping from valves or pipe connections which are highly pressurized.

HERO PRECAUTIONS

The hazards of electromagnetic radiation to ordnance (HERO) problem has become acute. The number and variety of electrically initiated explosive devices are increasing rapidly. At the same time, the power of communications and radar transmitting equipment is constantly being increased and the frequency spectrum broadened.

The exact chances of electroexplosive devices firing are quite unpredictable. The initiating elements of those devices need only to be supplied with the proper amount of electrical energy for a premature actuation to take place.

Radio-frequency energy can enter a weapon as a wave radiated through a hole or crack in the weapon skin. The energy may also be conducted into the weapon by the firing leads or other wires leading into the weapon.

The most susceptible periods are during assembly, disassembly, loading, unloading, or testing in electromagnetic fields. The most likely effects of premature actuation are dudding, reduction of the reliability of the device, or propellant ignition. In extreme cases, there is a definite possibility of warhead detonation.

Some specific safety precautions which the technician must observe with respect to these weapons and ordnance devices are:

- Turn off all rf transmitters during weapon handling operation in the area.
- Observe all local and general safety and HERO restrictions.
- Maintain radar silence during assembly, disassembly, loading, unloading, and testing operations.
- Avoid exposure of ordnance devices to high-power rf transmitters.

FIRE CONTROL SYSTEM OPERATION

Before you operate fire control equipment aboard ship, let us repeat that you should acquaint yourself thoroughly with the safety precautions provided in your system and equipment OPs. You must also become familiar with shipboard safety regulations. You will be taught how to apply many of these precautions while you are learning to operate fire control instruments. The following list of general precautions will assist you:

- Always inspect all train and elevation areas to make certain that all persons are clear, and that the areas are free of obstructions before operating directors or missile launchers.
- Always use warning bells before training or elevating launchers during routine work and practices.
- Before securing directors and launchers, always train and elevate them to stow positions; place all controls in the inoperative position, and deenergize all power supplied.
- During practices, slew directors and launchers only when it is necessary.
- Man all telephone stations when operating systems automatically or remotely.
- Notify all operators and persons concerned before shifting a system to automatic.
- Never operate directors or launchers in automatic without having the regular operators posted at their stations.
- Do not hesitate to stop any person from operating fire control equipment if this individual's actions might cause a personal casualty, a casualty to the equipment, or a casualty to any other person.

SUMMARY

Do not think that once you have learned all applicable safety precautions you can sit back and take things easy. Review them periodically, particularly those for jobs seldom performed. Try to improve upon any rules in effect. Safety is everyone's responsibility, not just those who drew up the regulations. Most accidents are caused by persons who are so familiar with their jobs they think they can take short cuts; by persons who do not know the applicable precautions; by practical jokers; or, in the majority of instances, by plain carelessness. Figure 4-11 shows what is left of a destroyer as a result of carelessness in handling ordnance material—a total of 167 persons dead or injured, plus the loss of a warship.

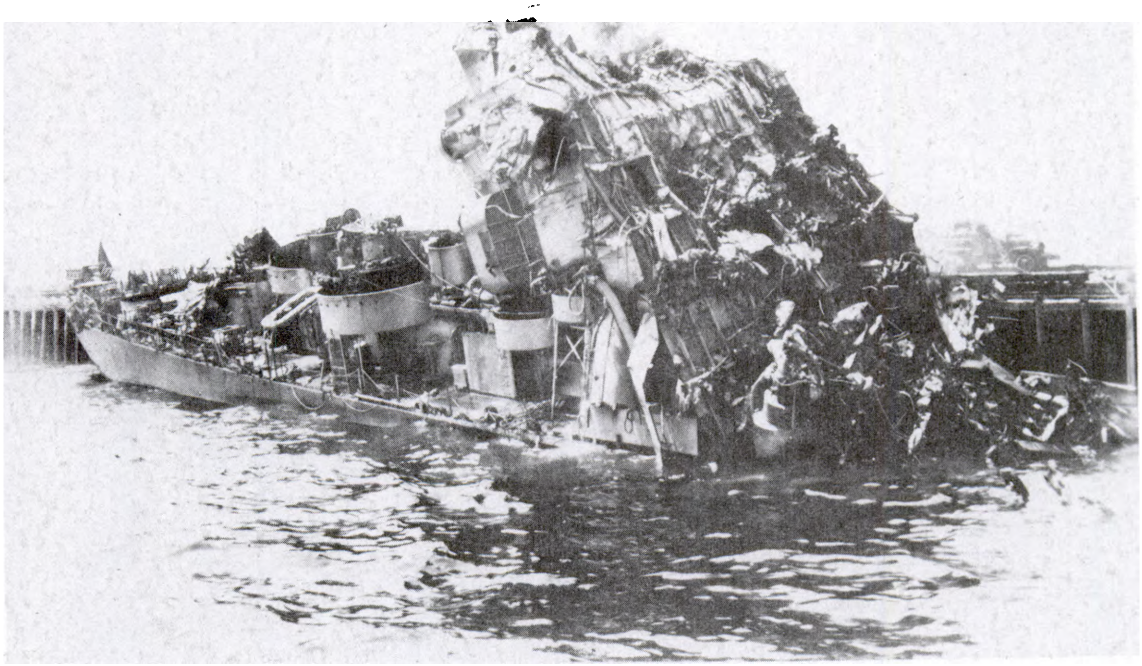

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Figure 4-11.—Result of mishandling ordnance material.

CHAPTER 5

FIRE CONTROL RADARS

As a result of earlier study, you are already acquainted with the major components of a typical fire control system. You know the job that each performs. You learned that the director uses radar or optical equipment or a combination of both to establish the line of sight to the target and thus determine its present position. You know that the target's present position quantities (range, bearing and elevation), measured by the radar or optical equipment, are transmitted to the fire control computer. The computer uses the target data and data from other sources to calculate launcher and missile orders.

This chapter attempts to provide you with an understanding of the principles of fire control radar as it applies to the guided missile weapon control system. Three-dimensional search radars (height-finders), although not fire control radars in the strict sense, are included in this chapter, since they are a major part of the weapon system and are maintained by missile fire control technicians.

BASIC RADAR PRINCIPLES

Let us briefly review the basic principles of radar in terms of general application. Radar is a term derived from the words RAdio Detection And Ranging. Radar is used to detect and range all objects within a large area surrounding the radar installation. For shipboard radar, the objects are normally such things as surface craft, aircraft, or missiles, and may be either friendly or hostile.

Radar operation depends upon the fact that the high-frequency radio waves that are radiated from a transmitter are reflected back toward the transmitter by all objects in the path of the waves. The objects must be within the range of the transmitter so that the reflected energy is of sufficient strength for the radar to detect it.

A very basic radar consists of a transmitter, a directional transmitting and receiving antenna, a receiver, and an oscilloscope (crt) type of indicator (fig. 5-1). Let us briefly consider the operation of the basic units by describing one cycle of transmission.

The transmitter sends (transmits) a short burst or pulse of high-frequency radio waves (rf energy). The transmission is aimed by the antenna causing the rf energy to be radiated through space. Objects within the space, such as airplanes or ships, are struck by the rf energy or pulse.

A small portion of the radio wave pulse (echo) is reflected back to the antenna, which is now functioning as a receiving antenna. The antenna and associated circuits detect the pulse and make it available to the receiver circuits.

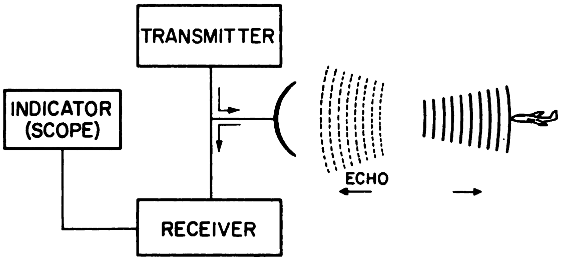

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Figure 5-1.—Basic radar operation.

The sensitive receiver amplifies the echo and displays it, along with a pulse that was generated at the time of transmission, on the oscilloscope.

The range of the ship or plane is measured by the time elapsed between the transmission and reception of the echo. This elapsed time is represented on the scope by a sweep trace that is marked off in miles or yards. The direction of the ship or plane causing the echo is determined by noting in which direction the antenna was aimed when the echo was received.

In actual operation, the radar transmits many pulses which occur at a high repetition rate. Insofar as display and time determinations are concerned, however, they can be thought of in terms of one transmitted pulse and one received echo. Radar operation is discussed in greater detail later in this chapter.

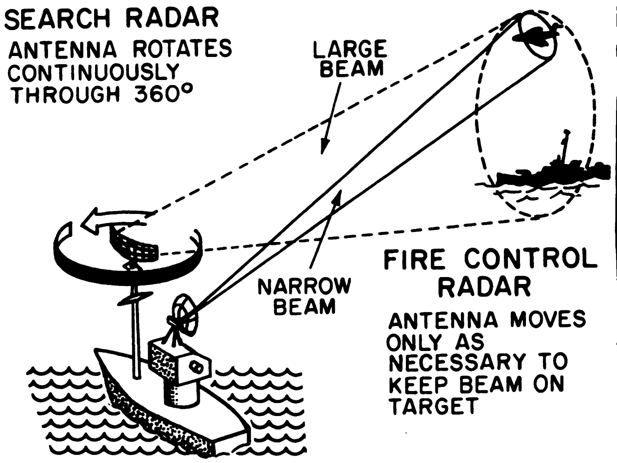
In order for an object to be detected, it must be in the unobstructed path of the antenna. Once an object is in that path, its detection depends upon the power of the transmitter and the sensitivity of the receiver.

Radar systems generally can be divided into two main groups—search radars and fire control radars. Search radars are used primarily for detection and surveillance of ships and aircraft. Fire control radars provide the precise target position information that is necessary for weapon system target engagement.

COMPARISON OF SEARCH AND FIRE CONTROL RADARS

There are two basic differences between a search radar system and a fire control radar system: (1) the shapes of the radar beams and the way they are moved, and (2) the accuracy of the range, bearing, and elevation data obtained.

The shapes of radar beams vary considerably, depending on the radar system. In general, however, search radar beams are much broader and higher than fire control radar beams, as illustrated in figure 5-2. (The exceptions would be the height-finder and multifunction radars). In addition, in order to scan the entire area around the ship, the antenna of a search radar system is rotated continuously through 360°. On the other hand, a fire control (FC) radar antenna, once it is aimed at the target, is moved only as necessary to keep the radar beam on the target.


SEARCH RADAR
ANTENNA ROTATES CONTINUOUSLY THROUGH 360°
LARGE BEAM
NARROW BEAM
FIRE CONTROL RADAR
ANTENNA MOVES ONLY AS NECESSARY TO KEEP BEAM ON TARGET

167.890

Figure 5-2.—Comparing radar beams.

The effectiveness of the ship's weapons depends very much on the accuracy of the target position information. Usually, the accuracy of the search radar data is limited because the radar beam covers such a large area that it is impossible to position it exactly. Also, the search antenna cannot be kept in one position in order to track a single target. It must provide a continuous picture of the entire surrounding area to prevent an enemy from approaching undetected. The narrow beam of a fire control radar, however, kept centered on the target, provides a means of determining target position with a high degree of accuracy.

A recent development in providing target position information is the automatic detection and tracking (ADT) capability. Through the use of digital data processing of target information, the search radar can effectively keep track of targets while scanning.

A further comparison can be made between the following characteristics of a typical search radar and a typical fire control radar. These differences affect such capabilities as effective range, range resolution, and angular resolution, and will be described in the next topic.

	AN/SPS-40A	AN/SPG-51C
Peak power (kw)	200	30
Average power (watts)	3600	750 minimum
Pulse width (μsec)	60	2-3
Beam height (deg)	19	1.6
Beam width (deg)	10	1.6

REQUIREMENTS OF FIRE CONTROL RADARS

One of the requirements of a fire control radar, as we have indicated, is that it be able to provide precise target range, bearing, and elevation information. As previously mentioned, this is accomplished by keeping the radar beam centered on the target and timing the return pulses.

Another requirement of a fire control radar is that it be able to distinguish between two or more targets located close to each other. This ability is referred to as resolution and is illustrated in the scope presentation of figure 5-3. The type of scope shown is a ppi scope, about which you will learn more later.

Next, we will discuss how certain radar characteristics affect the above mentioned requirements and the basic methods used to meet these same requirements. Let us begin with a review of the basic principles of radar energy transmission.

TYPES OF RADAR TRANSMISSION

Fire control radar systems employ two basic types of energy transmission: pulse and continuous wave (cw). The basic principle of pulsed radar is that the transmitter sends out radio waves in a series of short, powerful pulses, with periods of rest between the pulses. During the period in which the transmitter is at rest, echo signals may be received. The round trip time for these echo pulses to travel out and return is used to determine the range of the reflector object (target). In cw radar, on the other hand, the transmitter sends out a continuous signal. If a nonmoving target is in the path of the transmitted wave, the frequency of the reflected signal will be the same as that of the transmitted signal. If the target is moving, the frequency of the reflected signal will differ from that of the transmitted signal due to the Doppler effect, and the frequency difference can be used as an indicator of target motion.

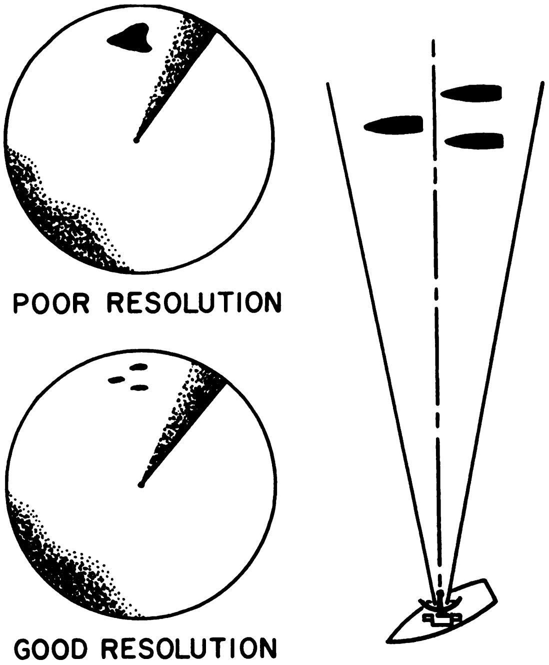


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Figure 5-3.—Target resolution.

PULSE

Pulse radar makes it possible to measure range in terms of the time interval between transmission of a pulse and the reception of an echo or reflected pulse from the target. The relationship of these pulses is shown in figure 5-4.

The pulse-repetition time must be of sufficient duration to allow the echo pulse to return from the maximum range of the radar set, otherwise the reception of an echo will be obscured by the succeeding pulse. The total time required for the completion of a cycle (the pulse duration plus the resting time) is called the repetition time. The reciprocal of repetition time is equal to the repetition frequency (prf) or rate (prr). The time necessary for a pulse to travel out and to return determines the maximum frequency which can be used for pulse repetition.

The minimum range at which a target can be detected is determined by the pulse width, pw. If a target is so close to the transmitter that the echo is received before the transmitter is cut off, the echo reception will be almost completely obscured by the more powerful transmitted pulse. Because the pulse-duration time must be short to increase reception of nearby targets and yet contain sufficient power to ensure a return echo of sufficient magnitude from the maximum range of the radar set, extremely large transmitted power outputs are required. The useful power of the transmitter is contained in the radiated pulses and is termed the peak power of the radar.

Since the radar is not transmitting for much of its total cycle, the average power is quite low when compared with the peak power during the pulse time. The relationship between the average power dissipated over the entire cycle and the peak power developed during the pulse time can be expressed by the following equation:

$$\frac{\text{average power}}{\text{peak power}} = \frac{\text{pulse width (pw)}}{\text{pulse repetition time}}$$

The greater the pulse width, the higher the average power; the longer the pulse-repetition time, the lower the average power. The relationship between pulse width and pulse-repetition time and between average power and peak power may be expressed as a duty cycle and represented as:

$$\frac{\text{pulse width (pw)}}{\text{pulse repetition time}} = \frac{\text{average power}}{\text{peak power}} = \text{duty cycle}$$

Or, since pulse-repetition time is the reciprocal of pulse repetition frequency, duty cycle can be derived from:

$$\text{pw} \times \text{prf} = \text{duty cycle}$$

For example figure 5-5 shows a 2-microsecond (μs) pulse repeated at a frequency of 5,000 hertz (Hz). This represents a duty cycle of .01, since the time for one cycle is 1/5,000 of a second, or 200 microseconds.

$$\frac{2\ \mu\text{sec}}{200\ \mu\text{sec}} \text{ or } .000002 \times 5000 = .01\ (1\%) = \text{duty cycle}$$

Assume a peak power of 2,000 kilowatts (kW), for 2 microseconds. Since average power = peak power x duty cycle then the average power = 2000 kilowatts x .01 = 20 kilowatts.

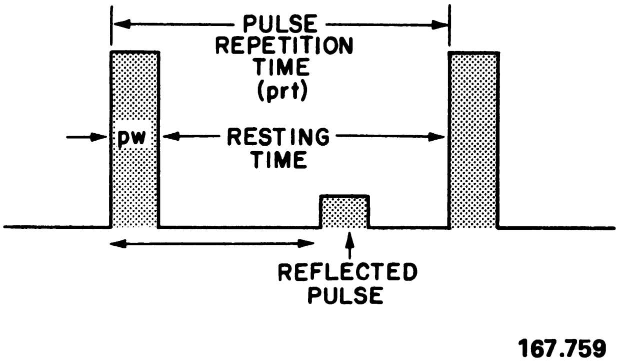

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Figure 5-4.—Pulse repetition time.

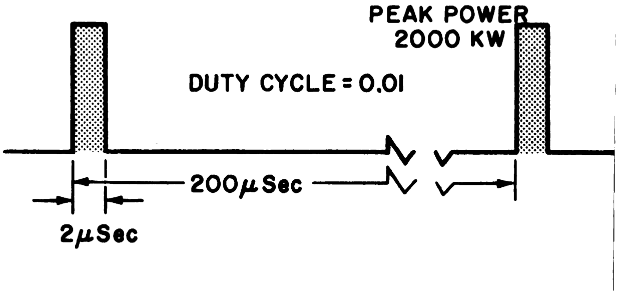

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Figure 5-5.—Duty cycle.

Range Determination

The effectiveness of range determination depends primarily on the ability of the radar to measure distance in terms of time. Electromagnetic radiation travels in space at a constant velocity of 186,300 miles per second. When it is reflected there is no loss of velocity, but merely a redirecting of the energy path. Range is then determined by the time required for a two-way energy transmission. The determination of range can be made by using the equation

$$R = \frac{ct}{2}$$

where R = the distance or range from the radar set to the target
c = the speed of propagation of the radio waves in air
t = the time required for the two-way trip

The velocity of electromagnetic radiation is approximately

1. 186,300 mi/s
2. 984 ft/μs
3. 328 yds/μs

Fire control radar sets usually display distance in yards. Using the approximation of 2,000 yards equal to 1 nautical mile, the time required for radio waves (rf) to travel 1 nautical mile and then return (total travel of 4,000 yards) is 12.2 microseconds.

$$\frac{4000 \text{ yds}}{328 \text{ yds}/\mu\text{s}} = 12.2\ \mu\text{s}$$

A more convenient figure is generally used. This figure is 6.1 microseconds, which is the roundtrip echo time for a target 1,000 yards away (one-half of a nautical mile).

CONTINUOUS WAVE (DOPPLER)

When radio-frequency energy which is transmitted from a fixed point continuously strikes an object which is moving toward or away from the source of the energy, the frequency of the reflected energy is changed. This change in frequency is known as the Doppler effect, or shift. The difference in frequency between the transmitted and the reflected energy determines the presence and relative speed of the moving target.

A common example of the Doppler effect is the changing pitch of the whistle of an approaching train. The train's whistle appears to change its pitch from a high tone as the train approaches to a lower tone as it moves away from the observer. As the train approaches, there is an apparent increase in frequency—a rising of the pitch; as the train moves away, there is an apparent decrease in frequency—a lowering of the pitch. This is the Doppler effect.

The Doppler shift has important operational applications aboard ship in determining target motion. If a target is moving, its radial velocity (velocity relative to the tracking radar) can be measured by comparing the transmitted frequency with the reflected frequency, which will be different due to the Doppler shift. The difference or beat frequency (f_d), which is also called the Doppler frequency, is proportional to the target radial velocity and the transmitted frequency. A typical Doppler radar has a frequency shift of 20 hertz per knot of target radial velocity. (Remember that the amount of shift will also change with a change in transmitter frequency.)

To track a target with cw Doppler radar, range information is required, but f_d is not a function of range. However, if two separate transmitters operating at two different frequencies, f1 and f2, are employed, then the relative phase between the two Doppler frequencies is a linear function of range to the target. In this system a mixer is used to combine the two transmitted frequencies and separate the two received frequencies to permit the use of one transmitting and one receiving antenna.

Instead of combining the two transmitter frequencies, the same result can be achieved by sweeping a transmitter frequency uniformly in time to cover the frequency range between two frequency limits, f1 to f2. The beat frequency f_d

between the transmitted and received signals is then a function of range. In this type of radar the velocity as well as the range is measured so that the velocity information, which is the rate of change of range, can be used to control range and velocity gates for range tracking.

PULSED DOPPLER

Pulse radars may be modified in one of several ways to employ the target Doppler frequency to detect a target's movement. The Doppler shift affects the pulse width and carrier frequency. A pulse radar can be designed to recognize one of these effects.

In a pulse Doppler radar, a stable cw reference oscillator signal, which is locked in phase with the transmitted signal during each transmitted pulse, is mixed with target echo signals to produce a beat signal. Since the reference oscillator and the transmitter are locked in phase, the echos, in effect, are compared with the transmitted signals.

The phase relationship between the echos from fixed targets and the transmitted signal is constant; therefore, the amplitude of the beat signal remains constant. Beat signals of varying amplitude indicate a moving target, because the phase difference between the reference oscillator signal and the target signal changes as target range changes.

The beat signals are subtracted in the radar receiver. This causes the fixed target signals, which are of constant amplitude, to cancel out. The signals from a moving target, which cause a phase difference, do not cancel and are sent to the radar scope for display.

The pulsed Doppler radar, therefore, has the range determining characteristics of a pulse radar and the velocity discriminating characteristics of a cw radar.

PRINCIPLES OF ENERGY TRANSMISSION

As a wave is propagated outward from the antenna, wavefronts form spherical surfaces that expand radially (fig. 5-1). If the antenna is directional (which is almost always the case), the distribution of power over the wavefront surface is not uniform (fig. 5-6). The power density (power per unit area) is greater at points within the beam (A) and small at points on the extremities of the beam (B). Points of no radiation are called null points (C). The power density decreases from a maximum at point A to zero at point C. The region of main radiation between C and C′ is called the main lobe, and regions of low radiation are called side lobes. The main lobe is normally specified by beam width, which is measured between the half-power level points.

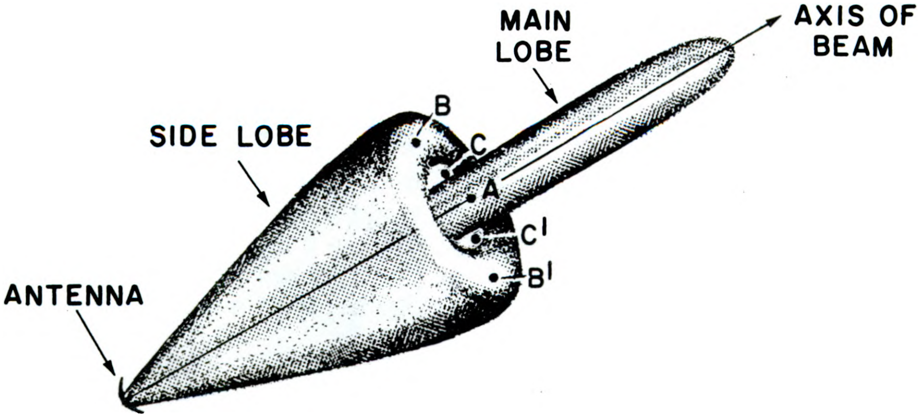

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Figure 5-6.—Radiation pattern from directional antenna.

BEAM REQUIREMENTS

The tactical application of the radar determines the requirements of the beam. When used for target tracking or missile guidance, operations that require extreme accuracy, the radar beam must be of narrow width and be propagated at high frequencies. The narrowness of the antenna beam determines the accuracy with which the radar can measure bearing and elevation. It also determines the angular resolution of the radar, in the same manner as pulse duration determines range resolution. Individual targets adjacent to one another can be detected if the radar set has a narrow beam and sends out a short pulse, as shown in figure 5-7.

BEAM POWER MEASUREMENTS

The relationship of maximum range to beam power characteristics is an important consideration.

The power of a radiated wave, such as a light wave, decreases as a function of the square of the distance between the source and the point of measurement. This same law holds here for the field intensity of electromagnetic waves when the power measured is considered in relation to the distance from the antenna. Target echo strength falls off very rapidly with an increase in range, and a large change in transmitted power will not greatly increase the range of the radar set. If, for example, the peak power is doubled, the range is increased by approximately only 19 percent.

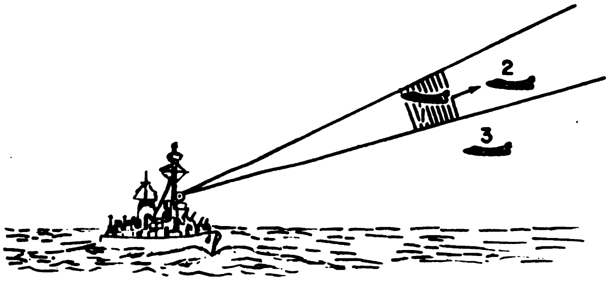

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Figure 5-7.—Radar tracking beam.

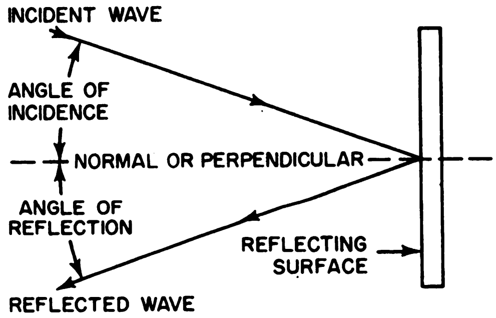
REFLECTION

The radar transmitter produces energy and the antenna radiates this energy into space, usually in the shape of a narrow beam. The reflection of the short wavelengths utilized by radar takes place from almost all objects in their paths. Aircraft, missiles, ships, water, or practically any material substance will reflect these short waves. The intensity of the reflected echo depends, among other things, upon the size and the shape of that object. From almost any shape some of the reflected energy will be returned to the source, and can be used to identify the target position.

When a radiated electromagnetic wave encounters a conducting surface, reflection of energy from the surface occurs. Reflection from the surface takes place in accordance with the law of reflection which states that the reflected and incident waves travel in directions which make equal angles with a line perpendicular to the reflecting surface (fig. 5-8). Uneven surfaces reflect in a multitude of directions, and such reflection is said to be diffused. By far the greatest loss which occurs in electromagnetic field intensity is a result of diffusion.

ANTENNAS

Let us briefly review the principles of electromagnetic wave radiation and reflectors in general before discussing some types of antennas used in fire control.

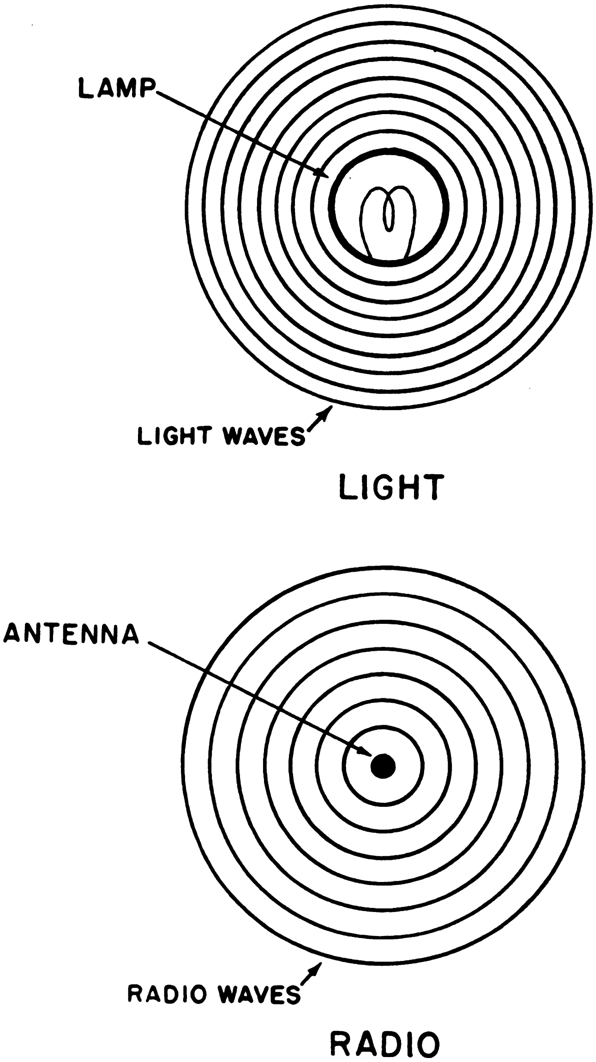


167.764

Figure 5-8.—Reflection.

The radar energy that forms the target tracking and illumination beams is transmitted by an antenna at the control point. Radiated energy tends to spread out equally in all directions, but by mounting a suitable reflector behind the antenna, a large part of the radiated energy can be formed into a relatively narrow beam.

Figure 5-9 compares the radiation from a radio antenna with that from a lamp. Both light waves and radio waves are electromagnetic radiation; the two are believed to be identical, except in frequency of vibration. From both sources, energy spreads out in the form of spherical waves. Unless they meet some obstruction, these waves will travel outward indefinitely at the speed of light.



144.38
Figure 5-9.—Radiation, unrestricted, from a lamp and from a radio antenna.

The energy at any given point decreases with range since the wave and therefore the energy is spreading out to cover a larger area. Because of its much higher frequency, light has a much shorter wavelength than a radio wave. This is suggested in figure 5-9, but it cannot be shown accurately to scale. The wavelength of radar transmission may be measured in centimeters; the wavelength of light varies from about three to seven ten-thousandths of a millimeter.

PARABOLIC REFLECTORS

You are, of course, familiar with the use of polished reflectors to form beams of light. An automobile headlight is an example of such a reflector. It, however, produces a fairly wide beam. A spotlight produces a more narrow beam.

A type of reflector generally employed in missile fire control radars is the parabolic dish. It is similar in appearance to the reflector used in an automobile headlight. As we have indicated, one of the important advantages of radar operation in the microwave region of the electromagnetic spectrum is that microwaves have properties and characteristics similar to those of light. This permits the use of well-known optical design techniques.

The action of the reflecting surface of the antenna is a result of its parabolic shape and the fact that the rays striking and reflecting from the metallic surface make equal angles with the surface at the point of reflection. This action is illustrated in figure 5-10. As the waves strike the reflector they are straightened and concentrated into a narrow circular beam of energy containing parallel, flat wavefronts.

HORN RADIATORS

Horn radiators, like parabolic reflectors, may be used to obtain directive radiation of electromagnetic waves.

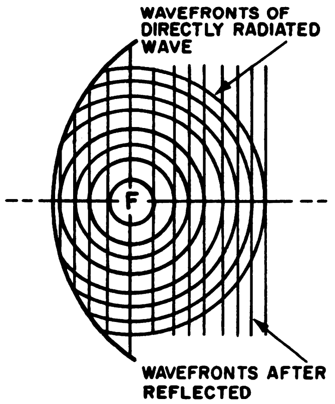

WAVEFRONTS OF DIRECTLY RADIATED WAVE
F
WAVEFRONTS AFTER REFLECTED

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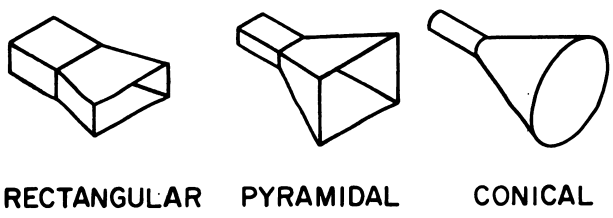
Figure 5-10.—Principles of the parabolic reflector.

The operation of a horn radiator as an electromagnetic directing device is analogous to that of acoustic horns. However, the throat of an acoustic horn usually has dimensions much smaller than the sound wavelengths for which it is used, while the throat of the electromagnetic horn has dimensions that are comparable to the wavelength being used.

Horn radiators are readily adaptable for use with waveguides because they serve both as an impedance-matching device and as a directional radiator. Horn radiators may be fed by coaxial or other types of lines.

Horns are constructed in a variety of shapes, as illustrated in figure 5-11. The shape of the horn, along with the dimensions of the length and mouth, largely determines the beam shape. The ratio of the horn length to mouth opening size determines the beam width and thus the directivity. In general, the larger the opening of the horn, the more directive is the resulting field pattern.



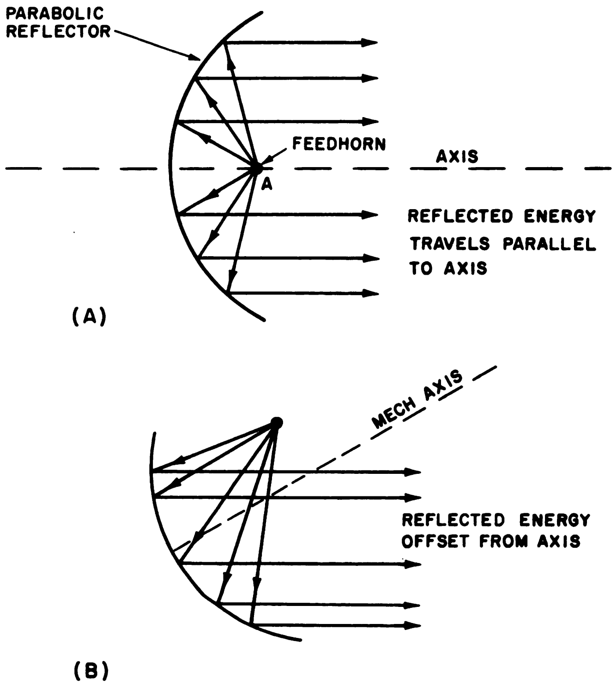
13.41

Figure 5-11.—Horn radiators.

FEEDHORNS

A waveguide horn may be used to feed into a parabolic dish. The directivity of this horn, or feedhorn, is then added to that of the parabolic dish. The resulting pattern (fig. 5-12A) is a very narrow and concentrated beam. Such an arrangement is ideally suited for fire control use. In most radars, the feedhorn is covered with a window of polystyrene fiberglass to prevent moisture and dirt from entering the open end of the waveguide.

One problem associated with feedhorns is the shadow introduced by the feedhorn if it is in the path of the beam. (The shadow is a dead spot directly in front of the feedhorn.) To solve this problem the feedhorn can be offset from center (fig. 5-12B). This takes it out of the path of the rf beam, thus eliminating the shadow.


PARABOLIC REFLECTOR
FEEDHORN
AXIS
A
REFLECTED ENERGY TRAVELS PARALLEL TO AXIS
(A)
MECH AXIS
REFLECTED ENERGY OFFSET FROM AXIS
(B)

1.49:25.226

Figure 5-12.—Reflector with feedhorn.

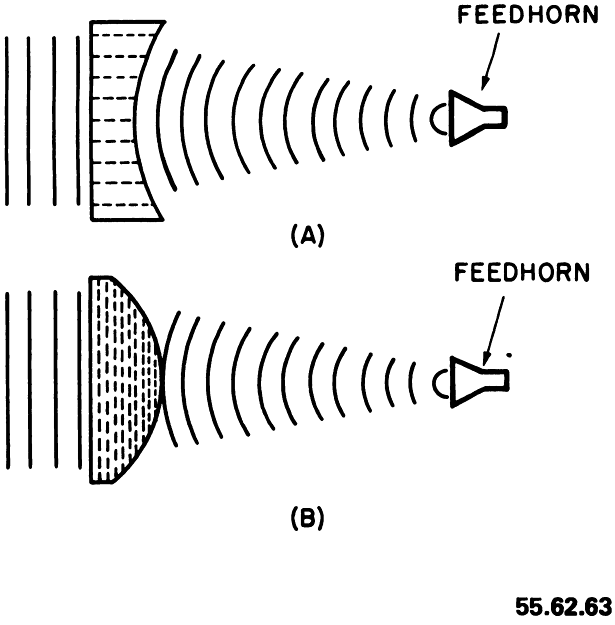
LENS ANTENNA

Another antenna that can change spherical waves into flat plane waves is the lens antenna, or microwave lens, which is similar to an optical lens. Just as light waves bend as they pass through an optical lens, electromagnetic waves bend as they pass through a microwave lens.

Lens antennas of two types have been developed to provide a plane-wavefront narrow beam for tracking radars, while avoiding the problems associated with feedhorn shadow in reflector antennas. These are the conducting (acceleration) type and the dielectric (delay) type.

The lens of an antenna is substantially transparent to microwave energy that is caused to pass through it. It will, however, cause the waves of energy to be either converged or diverged as they exit the lens. Consider the action of the two types of lens that we have mentioned.

First, the conducting type, which utilizes the principles of waveguide, is illustrated in figure 5-13A. The lens is placed in front of a point source of rf energy, such as a feedhorn. The feedhorn directs (radiates) the energy into the lens, which accelerates the wave transmissions as they pass through.



55.62.63

Figure 5-13.—Antenna lenses: A. Waveguide (acceleration) type of microwave lens: B. Metal strip (delay) type of microwave lens.

This type of lens consists of flat metal strips placed parallel to the electric field of the wave and spaced slightly in excess of one-half of a wavelength. To the wave these strips look like parallel waveguides. The velocity of phase propagation of a wave is greater in a waveguide than in air. Thus, since the lens is concave, the outer portions of the transmitted spherical waves are accelerated for a longer interval of time than the inner portion. The spherical waves emerge at the exit side of the conducting lens (lens aperture) as flat-fronted parallel waves. The waveguide type of lens is frequency sensitive.

The other type of lens is the dielectric, or metallic delay lens, shown in figure 5-13B. The delay lens, as its name implies, slows down the phase propagation as the wave passes through it. This lens is convex and consists of dielectric material. Focusing action is a result of the difference in the velocity of propagation inside the dielectric compared with the velocity of propagation in the air. The end result is an apparent bending, or refracting, of the waves. The delay on the waves passing through the lens is determined by the dielectric constant of the material. In most cases, artificial dielectrics consisting of conducting rods or spheres that are small compared to the wavelength are used. In this case, the inner portions of the transmitted waves are decelerated for a longer interval of time than the outer portions.

In a lens antenna the exit side of the lens can be regarded as an aperture across which there is a field distribution. This field acts as a source of radiation, just as do fields across the mouth of a reflector or horn. For a returning echo, the same process takes place in the lens.

It can be seen that the reflector uses the law of reflection while the lens uses the law of refraction. The rear feed arrangement of the lens antenna puts the radiator out of the path of the beam, thus reducing shadows.

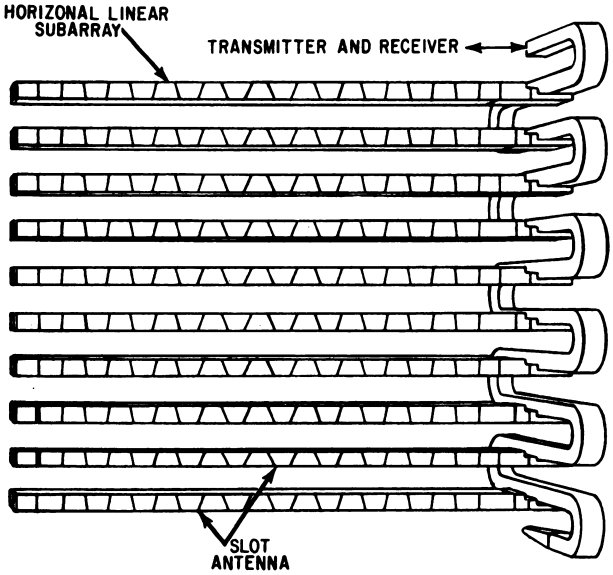
ARRAY ANTENNAS

An array type of antenna is just what the name implies—an array or regular grouping of individual radiating elements. These elements may be dipoles, waveguide slots, or horns. The most common form of array is the planar array which consists of elements linearly aligned in two dimensions—horizontal and vertical—to form a plane (fig. 5-14).

Unlike the lens or parabolic reflector, the array applies the proper phase relationship to make the wavefront flat before it is radiated by the source feed. The relative phase between elements determines the position of the beam, hence the often used term phased array. This phase relationship is what allows the beam to be rotated or steered without moving the antenna. This characteristic of array antennas makes it ideal for electronic scanning or tracking. Scanning will be discussed shortly.

RADAR BEAM PATTERNS

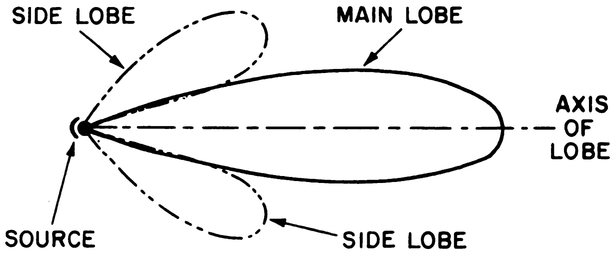
When the radar is receiving reflected energy, the incoming rays are concentrated and focused on the feedhorn only when they enter the dish in perfectly parallel rays (similar to the pattern depicted in figure 5-12). The waves reflected from the target, under ideal conditions, will be parallel if they are transmitted in this form. Therefore, we can state that in any antenna system the transmitting and receiving patterns are essentially the same. For this reason one antenna can be used for transmission and reception. The parabolic reflector produces a "pencil beam" in which most of the energy is confined to a small cone of nearly circular cross section. The concentration of the energy into a beam increases the amount of energy hitting the target.



167.855

Figure 5-14.—Planar array antenna.

However, no radar can produce an ideal beam of parallel rays. For one thing, the end of the waveguide is large, compared to the ideal point source. For another, a reflector of practical size is not sufficiently large compared with the wavelength of the radiated energy. A radar beam therefore diverges and forms a lobe, like the one in figure 5-15. This is the main lobe or beam. It should be understood that such a lobe is merely a convenient way of representing the beam on paper; it is in no sense a "picture" of the beam. Some of the radiated energy will be scattered outside the main lobe, and will form side lobes, usually of lesser strength and much shorter effective range. They are undesirable lobes that exist in close proximity to the transmitter. The radiation does not end abruptly at a certain distance from the transmitter, as the diagram implies. The lobe, if it can be pictured in three dimensions, can be thought of as a surface, all parts of which receive an equal amount of energy. This can be considered the minimum energy that is useful for our purpose (missile guidance or target tracking). The lobe in figure 5-15 is not drawn to scale. The diameter of the reflector is on the order of 2 feet; the length of the lobe may be from 20 to 50 miles.



33.146

Figure 5-15.—Lobe formation of a radar beam.

Its useful width may be 4° or 5°. At any given distance from the transmitter, the signal is strongest along the axis of the lobe.

SCANNING

The systematic movement of a radar beam while searching for or tracking a target is referred to as scanning or lobing. The type and method of scanning used depend on the purpose and type of radar and on the antenna size and design.

Assume that a target is somewhere on the lobe axis, and that the receiver is detecting signals reflected from the target. If these reflected signals decrease in strength, it will be apparent that the target has flown off the axis, and that the beam must be moved to keep the lobe axis on the target. The beam could be moved by an operator who is tracking the target with an optical sight; but such tracking would be slow and inaccurate, and would be limited by conditions of visibility. An automatic tracking system is required that can SCAN, or search, the target area.

Two basic methods of accomplishing scanning are mechanical and electronic. In mechanical scanning, the beam can be moved in various ways. The entire antenna can be moved in the desired pattern; the feeder can be moved relative to a fixed reflector; or the reflector can be moved relative to a fixed source. In electronic scanning, the beam is effectively moved by such means as switching between a set of feeder sources; varying the phasing between elements in a multielement array; and comparing the amplitude and phase differences between signals received by a multielement array. A combination of mechanical and electronic scanning is also used in some antenna systems.

MECHANICAL SCANNING

A common form of scanning for target tracking is conical scanning. This is generally accomplished mechanically by nutating the rf feed point.

Nutation is difficult to describe in words, but easy to demonstrate. Hold a pencil in two hands; while holding the eraser end as still as possible, swing the point through a circle. This motion of the pencil is nutation. (The pencil point corresponds to the open, or transmitting, end of the waveguide antenna.) The important thing to note is that the polarization of the beam is not changed during the scanning cycle. This means that the axis of the moving feed does not change horizontal or vertical orientation while the feed is moving. You might compare the movement to that of a ferris wheel; that is, the seat remains vertical regardless of the position of the wheel.

Nutating Waveguide

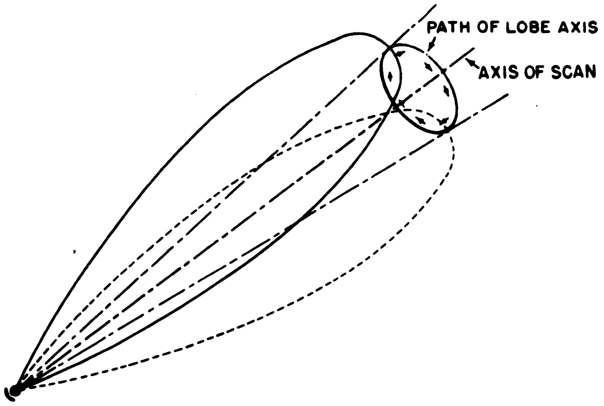
A waveguide is a metal pipe, usually rectangular in cross section, which is used to conduct the rf energy from the transmitter to the antenna. The open end of the waveguide faces the concave side of the reflector, and the rf energy it emits is bounced from the reflector surface.

A conical scan can be generated by nutation of the waveguide. In this process, the axis of the waveguide itself is moved through a small conical pattern. This three-dimensional movement in an actual installation of the waveguide is fast and of small amplitude. To an observer, the waveguide appears merely to be vibrating slightly.

Nutating Lobe

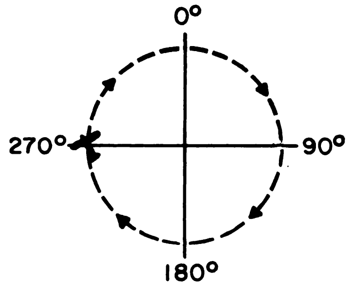
By movement of either the waveguide or the antenna it is possible to generate a conical scan pattern, as shown in figure 5-16. The axis of the radar lobe is made to sweep out a cone in space. The apex of this cone is, of course, at the radar transmitter antenna or reflector. At any given distance from the antenna, the path of the lobe axis is a circle. Within the useful range of the beam, the inner edge of the lobe at all times overlaps the axis of scan.

Now, assume that we use a conically scanned beam for target tracking. If the target is on the scan axis, the strength of the reflected signals will remain constant (or change gradually as the range changes). But if the target is slightly off

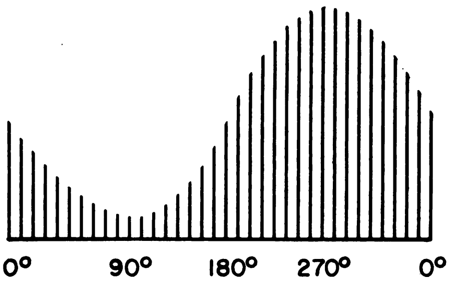


33.113
Figure 5-16.—Nutating lobe, conical scanning.

the axis, the amplitude of the reflected signals will vary at the scan rate. For example, if the target is to the left of the scan axis (fig. 5-17), the reflected signals will be of maximum strength as the lobe sweeps through the left part of its cone and will quickly decrease to a minimum as the lobe sweeps through the right part. Information on the instantaneous position of the beam relative to the scan axis, and on the strength of the reflected signals, can be fed to a signal processor. This processor in the radar may be called an angle tracker or an angle error detector. If the target moves off the scan axis, the error detector instantly determines the direction and amount of antenna movement required to continue tracking. The error detector output can be used to control servomechanisms that move the antenna, so that the target will be tracked accurately and automatically.



PATH OF BEAM DURING SCANNING



12.321
Figure 5-17.—Reflected signal strength.

When a conically scanned radar beam is used for missile guidance, the desired path of the missile is not along the axis of the beam, but along the axis of the scan.

ELECTRONIC SCANNING

Electronic scanning can accomplish lobe motion more rapidly than, and without the inherent disadvantages of, the mechanical systems. Because electronic scanning cannot generally cover as large a volume in space, however, it is sometimes combined with mechanical scanning in particular applications.

Monopulse

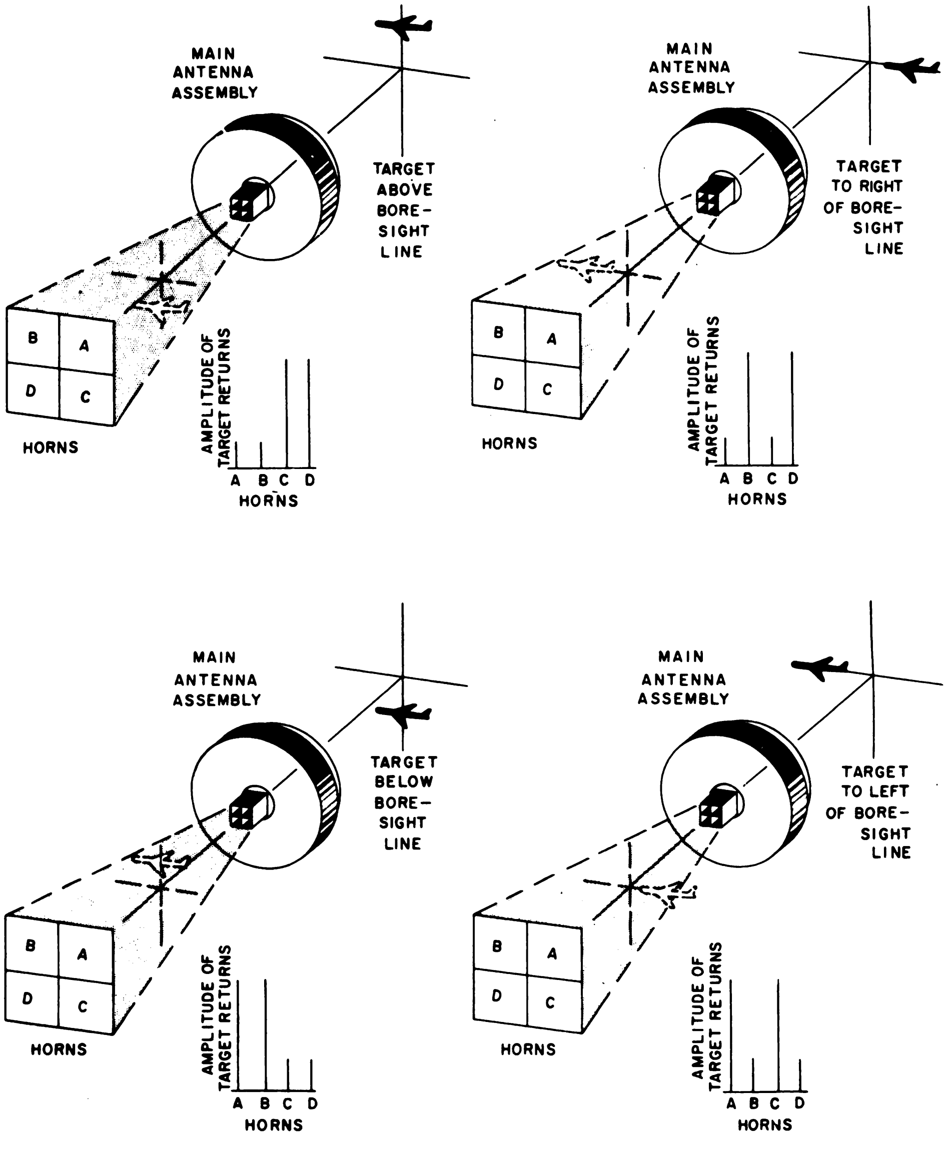
With monopulse or simultaneous lobing, all range, bearing, and elevation angle information about a target is obtained from, as the name implies, a single pulse.

For target tracking, the radar discussed here produces a narrow circular beam of pulsed rf energy at a high pulse repetition rate. Each pulse is divided into four signals which are equal in amplitude and phase. The four signals are radiated at the same time from each of four feedhorns grouped in a cluster. The radiated energy is focused into a beam by a parabolic reflector of the type mentioned previously. Energy reflected from targets is refocused by the reflector into the feedhorns. The amount of the total energy received by each horn will vary, depending on the position of the target relative to the beam axis. This is illustrated in figure

5-18 for four targets at different positions with respect to the beam axis.

The amplitude of the returned signals received by each horn is continuously compared with those received in the other horns, and error signals are generated which indicate the relative position of the target with respect to the axis of the beam. Angle servo circuits receive these error signals and correct the position of the radar beam to keep the beam axis on target.

The traverse (train) signal is made up of signals from horns A and C added together, and from horns B and D added. By waveguide design the sum of B and D is made 180° out of phase with the sum of A and C. These two are combined and the traverse signal is the difference of (A + C) - (B + D). Since the horns are positioned


MAIN ANTENNA ASSEMBLY
TARGET ABOVE BORE-SIGHT LINE
B
A
D
C
HORNS
AMPLITUDE OF TARGET RETURNS
A B C D
HORNS
MAIN ANTENNA ASSEMBLY
TARGET TO RIGHT OF BORE-SIGHT LINE
B
A
D
C
HORNS
AMPLITUDE OF TARGET RETURNS
A B C D
HORNS
MAIN ANTENNA ASSEMBLY
TARGET BELOW BORE-SIGHT LINE
B
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D
C
HORNS
AMPLITUDE OF TARGET RETURNS
A B C D
HORNS
MAIN ANTENNA ASSEMBLY
TARGET TO LEFT OF BORE-SIGHT LINE
B
A
D
C
HORNS
AMPLITUDE OF TARGET RETURNS
A B C D
HORNS

257.29

Figure 5-18.—Variation of received energy with target position.

as shown in figure 5-18, the relative amplitudes of the horn signals give an indication of the magnitude of the traverse error. The elevation signal consists of the signals from horns C and D added 180° out of phase with A and B, i.e., (A + B) - (C + D). The sum or range signal is composed of signals from all four feedhorns added together in phase. It provides a reference from which target distance from the center of the beam axis is measured. The range signal is also used as a phase reference for the traverse and elevation error signals.

The traverse and elevation error signals are compared in the radar error detector with the range or reference signal. The output of the error detector may be positive or negative pulses, the amplitude of which is proportional to the angle between the beam axis and a line drawn to the target. The polarity of the output pulses indicates whether the target is above or below, to the right or to the left of the beam axis. Of course, if the target is directly on the line of sight, the output of the error detector is zero, and no angle tracking error is produced.

An important advantage of a monopulse tracking radar over one using conical scan is that the instantaneous angular measurements are not subject to errors caused by target scintillation. (As the target maneuvers or moves, the radar beams bounce off different areas of the target and cause random reflectivity which may lead to tracking errors.) A monopulse tracking radar is not subject to this error because each pulse provides an angular measurement without regard to the rest of the pulse train; no cross-section fluctuations can affect the measurement.

An additional advantage of monopulse tracking is that no mechanical action is required, such as a whirling scanner to accommodate while trying to do precise tracking.

COnical Scan on Receive Only

Another type of scanning uses a cluster of feedhorns similar to monopulse. The difference is that a scanner uses the difference signals to amplitude modulate the sum signal at the COSRO scan frequency. This scanner is bypassed during transmission, hence the name conical scan on receive only, or just COSRO. Unlike monopulse, the angle information is recovered during one complete cycle of the scanner. In a high pulse repetition rate radar, this would consist of many pulses.

With a target that is centered in the beam, the amplitude of the signals at each feedhorn is the same. But when the target is off center, the output of the scanner appears as in figure 5-17. The pulses are effectively amplitude modulated. The amount of modulation is determined by the target's distance from the beam's center, and the phase is determined by the target's direction from the beam's center. The frequency of modulation is the same as the scan rate.

An advantage of COSRO is that the scan frequency is not transmitted to the target, thereby decreasing the possibility of jamming.

BEAM STEERING

The position of the beam of an array antenna, as mentioned previously, is determined by the relative phase of the signals at each element. When the phase of the signals applied to each element is varied, the beam can be effectively steered without moving the array antenna. This is illustrated in figure 5-19. When the phase of the rf energy at each element is the same, maximum energy is radiated from each element at the same time. This results in a plane wavefront which is parallel to the array and a direction of beam maximum which is perpendicular to the array (fig. 5-19A).

When the phase is changed between elements, maximum energy arrives at each slot at different times, resulting in the wavefront shown in view B of figure 5-19. The amount and speed at which the beam is steered depends on the amount of phase shift and how fast the shift occurs. With today's technology in solid-state devices, the speed can be many times greater than that attained by mechanical means.

By dividing the array into quadrants, angle information can be acquired as in the monopulse method. Therefore, array antennas can be used for tracking as well as searching.

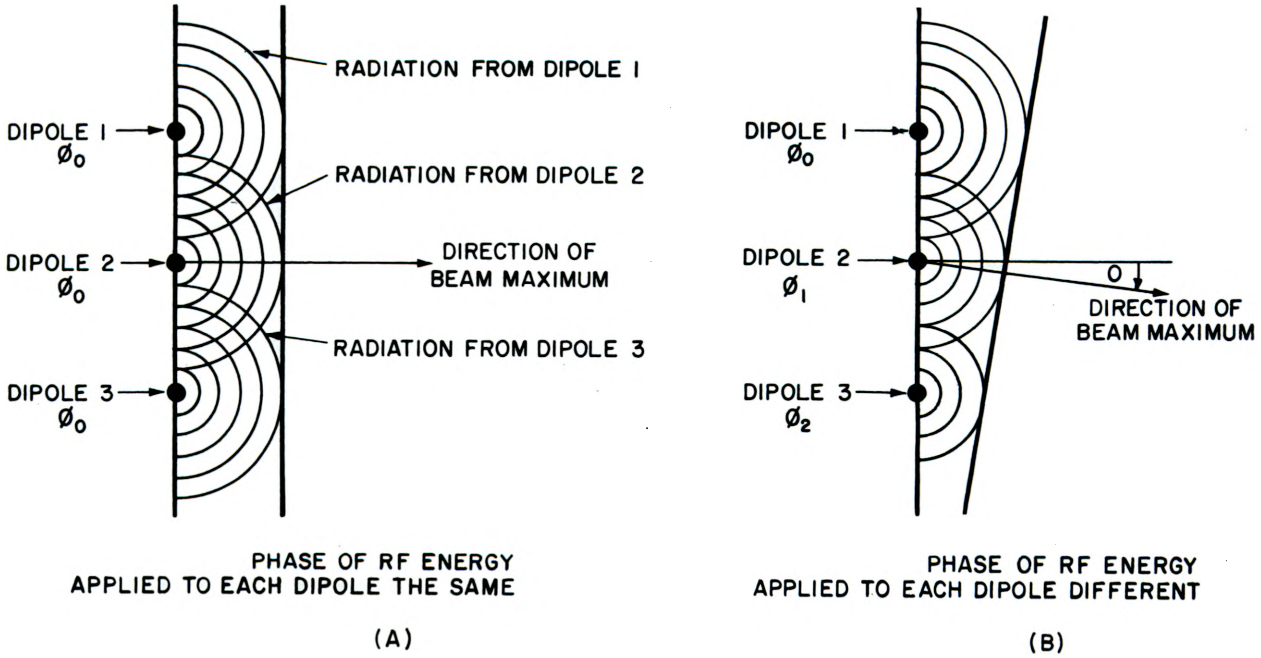
RADIATION FROM DIPOLE 1
DIPOLE 1
Ø0
RADIATION FROM DIPOLE 2
DIPOLE 2
Ø0
DIRECTION OF BEAM MAXIMUM
RADIATION FROM DIPOLE 3
DIPOLE 3
Ø0
PHASE OF RF ENERGY APPLIED TO EACH DIPOLE THE SAME
(A)
DIPOLE 1
Ø0
DIPOLE 2
Ø1
θ
DIRECTION OF BEAM MAXIMUM
DIPOLE 3
Ø2
PHASE OF RF ENERGY APPLIED TO EACH DIPOLE DIFFERENT
(B)

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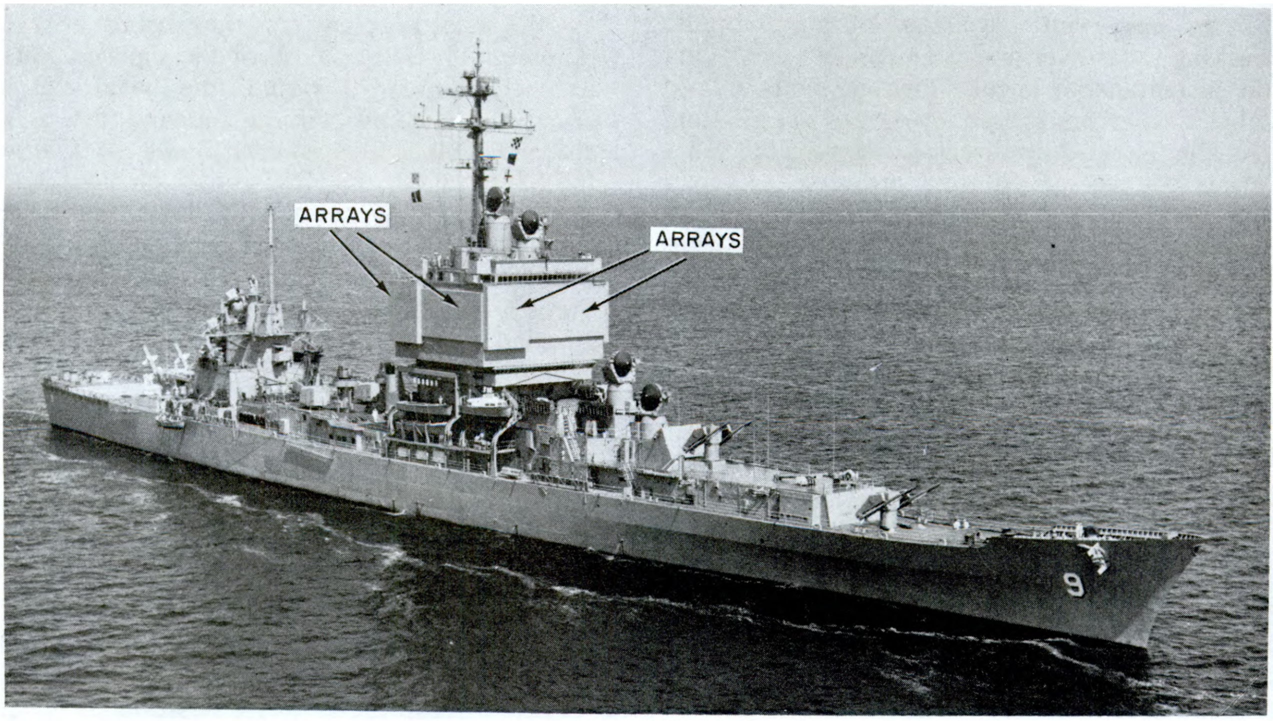
Figure 5-19.—Beam steering.



134.82-9

Figure 5-20.—USS *Long Beach* (CGN-9).

Some height-finder radars in the SMS fleet use frequency scanning to achieve beam steering. Actually, this is just a method of changing the phase between each element. Array radars, such as those installed on the USS *Long Beach* (fig. 5-20) and the CG-47 class ships (fig. 5-21), use electronically controlled phase shifters.

RANGE TRACKING

Effective range tracking is necessary in fire control. The automatic acquisition and subsequent tracking of a target in range is accomplished by the use of acquisition and tracking gates. When a target is first designated, the radar receiver circuits position a set of acquisition gates to coincide in time with the designated range of the target (fig. 5-22A). If the target echo is located somewhere other than the center of the track gate, an error signal is developed which drives the track gate to center it on the target (fig. 5-22B). As target range changes, the gate is constantly driven to keep it centered on the target. The position of the track gate is then an accurate indication of target range.

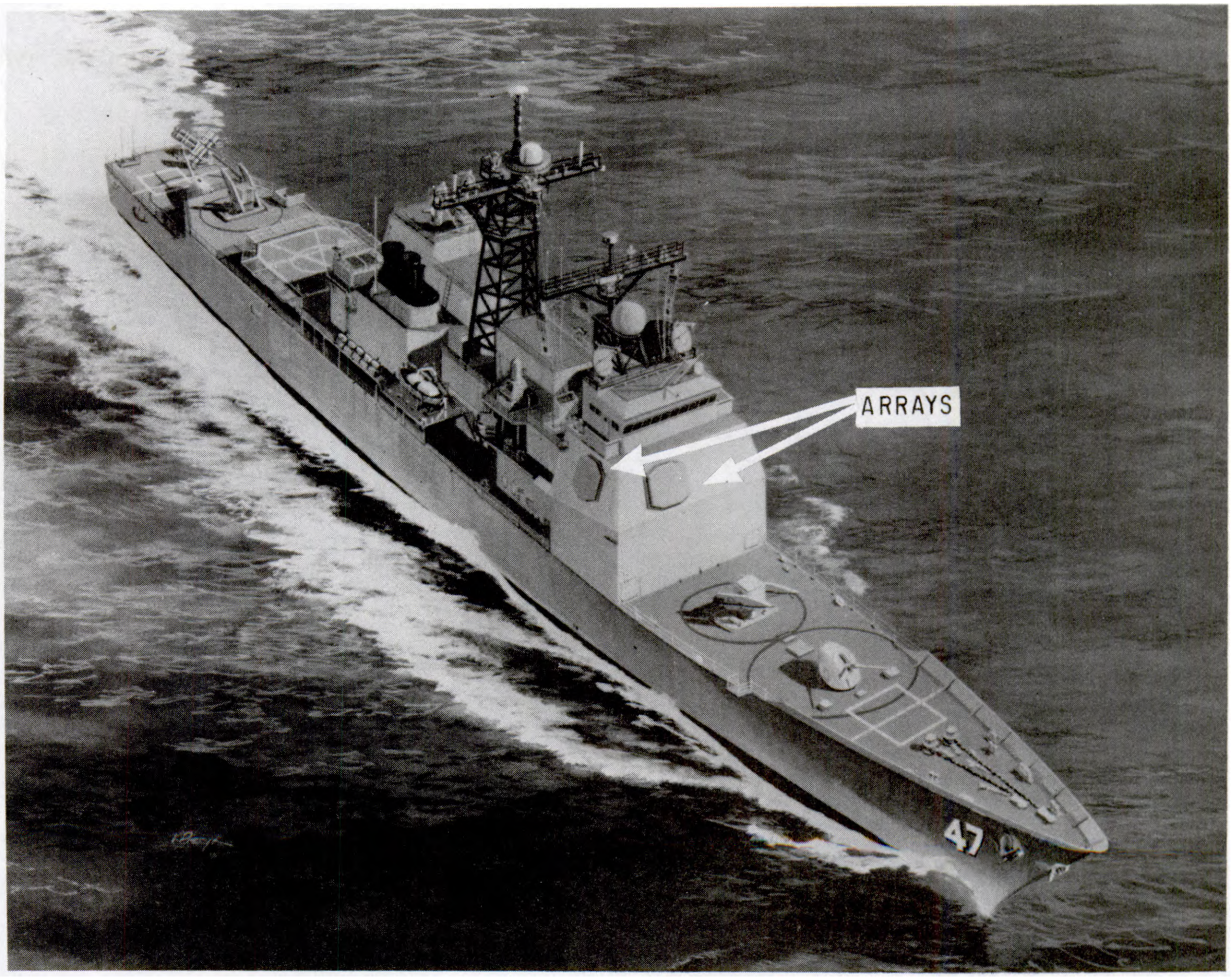


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Figure 5-21.— USS *Ticonderoga* (CG-47).

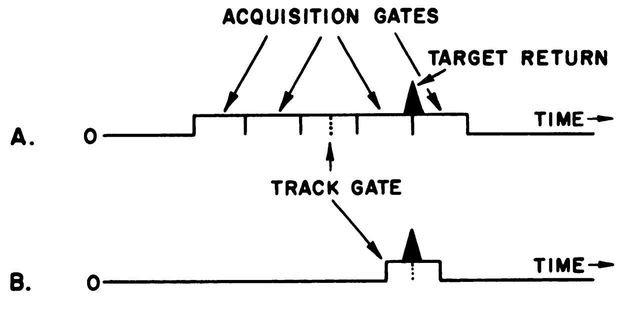

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Figure 5-22.—Range tracking.

RADAR SYSTEMS

Radar systems vary greatly in detail. The basic components, however, that make up any radar are usually the same as those which make up the pulse radar. For this reason, a discussion of pulse radar basic components and their functions is presented. The discussion, for the most part, applies to all radar systems.

PULSE RADAR

The block diagram shown in figure 5-23 includes the basic components that comprise a pulse radar system. The functional breakdown resolves itself into seven essential components:

1. Timer—The timer synchronizes the modulator pulse with the initiation of the time base in the indicator unit.

2. Modulator—The modulator provides a high-voltage pulse which modulates or triggers the transmitter.

3. Transmitter—The transmitter generates rf energy in the form of a high-power pulse when triggered.

4. Antenna system—The antenna has two prime purposes:

(1) Radiates the rf energy output of the transmitter in a highly directional beam

(2) Detects or receives returning echo energy and forwards it to the receiver

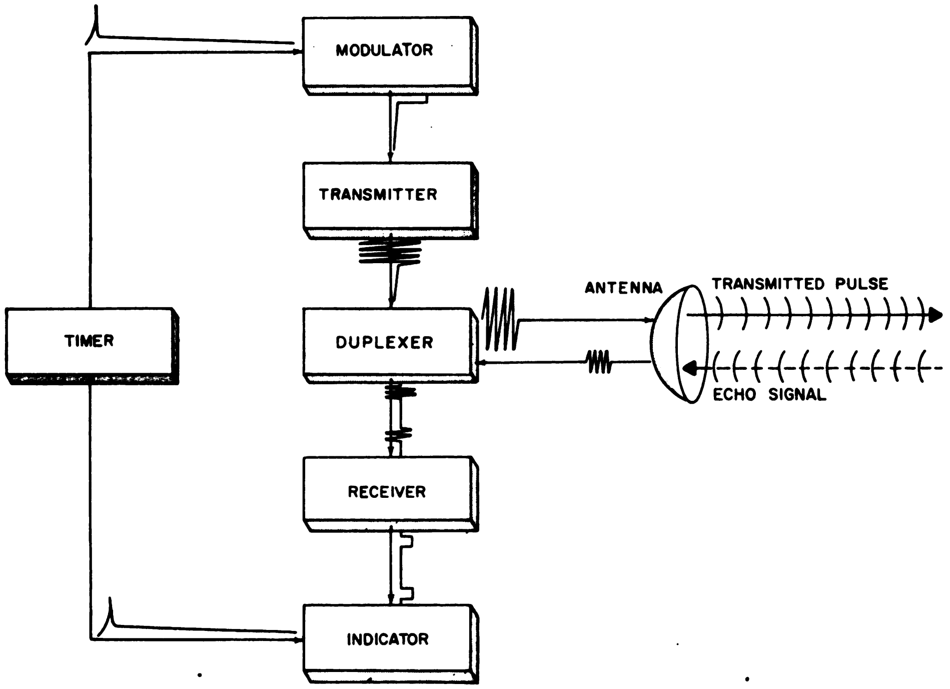

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Figure 5-23.—Basic pulse radar, simplified block diagram.

5. The duplexer–Most radar sets employ a single antenna for both transmission and reception. This device assures that the receiver presents a high-impedance path to the transmitted energy during periods in which the radar set is transmitting and that this impedance is eliminated during periods in which the set is receiving. It is commonly known as the duplexer or tr (transmit-receive) switch.

6. Receiver–The receiver amplifies and detects echo pulses, extracts range and angle error information for automatic tracking, and produces amplified output video pulses for the indicator.

7. Indicator–The indicator provides the visual display of radar information.

CW DOPPLER RADAR

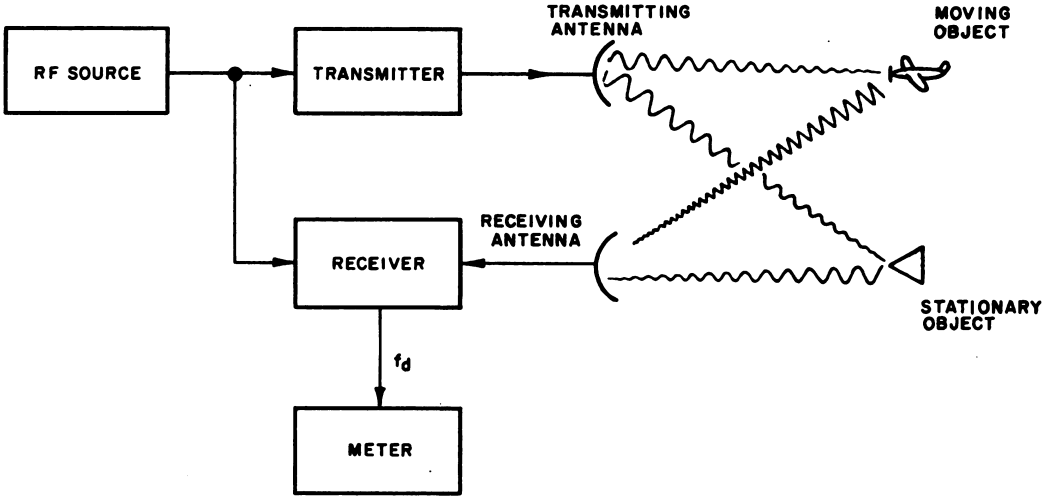
In conventional pulse radars, echos from stationary objects usually clutter indicators so that it is difficult, if not impossible, to distinguish aircraft echos from stationary echos such as land masses, cloud formations, and the like. For this reason, the Doppler principle is used in the tracking radar because of its excellent velocity discrimination capabilities.

Good velocity discrimination and clutter rejection are attainable through the use of a continuous-wave (cw) radar utilizing the Doppler principle. Basically, a cw radar transmits a continuous signal on one antenna and receives echo signals on another (fig. 5-24).

A cw rf source generates a very stable rf signal, which is sent to the transmitter. A sample of this energy is also sent to the receiver. The transmitter amplifies and sends the signal to the antenna where it is radiated. When this radiated signal strikes an object, it is reflected, picked up by the receiving antenna, and sent to the receiver, where it is mixed with the sample energy from the rf source. The difference frequency, f_d, between these two signals is detected and indicated on a meter; thus, the meter indicates velocity. Only a moving target will provide a difference frequency output from the receiver, because a moving target changes the frequency of reflected rf energy in proportion to the speed of the target. This frequency difference is the Doppler shift of the transmitted energy.

PULSED DOPPLER RADAR

The previously described cw Doppler radar can distinguish between fixed and moving targets and measure velocity, but cannot measure range.



167.523

Figure 5-24.–(U) Basic cw Doppler radar, simplified block diagram.

Pulse radars can measure range, but they cannot reject clutter echos from fixed targets. A combination of the two can be used to measure the range and the velocity of a moving target.

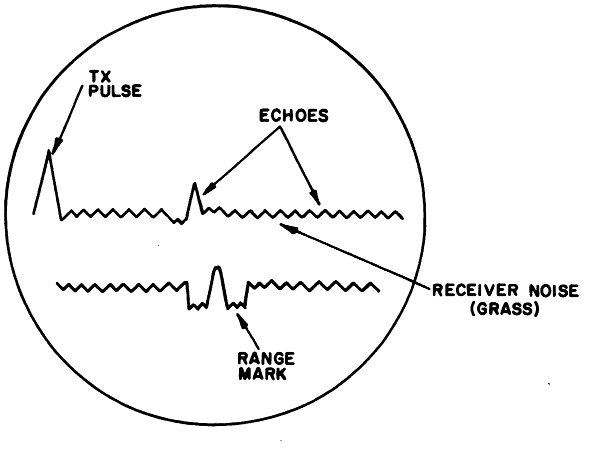
A pulsed Doppler radar has the advantages of both a pulse radar and continuous-wave radar. It has the range accuracy of the pulse radar combined with the velocity discrimination features of the cw radar. The velocity discrimination feature allows selection of targets according to radial velocity (range rate). In a cw radar a stationary target produces no Doppler shift in the frequency of the returning pulses; therefore, only moving targets will be selected and tracked. The pulse radar cannot readily discriminate between stationary and moving targets, and therefore, provides poor velocity information. The reason for pulsing a cw radar, making it a pulsed Doppler radar, is to obtain precise range information from the pulses returning from the target. Also, because it is not always radiating, the pulsed Doppler radar needs only one antenna. The basic components, then, would be the same as for a pulse radar.

RADAR INDICATORS

The radar set must furnish appropriate information to the operator. This is done by a visual presentation on an oscilloscope type of indicator. The scope images contain data of measurable quantities, including range, bearing, elevation, and speed. There are many methods of visually presenting the radar information. Four of the most common types are discussed here. These are the A-scope, the T & E scope, the RHI, and the ppi.

A-SCOPE

The A-scope presentation (fig. 5-25) is used to display range. The echo causes a vertical displacement of the electron beam, the amplitude of which depends on the strength of the returned signal pulse. The point on the horizontal base line at which the vertical displacement occurs indicates the range. Sometimes another sweep is included for a more precise range indication. This sweep represents only a small portion of the main sweep and is centered about either the track gate or a movable range mark.



55.124
Figure 5-25.—An A-scope presentation.

T & E SCOPE

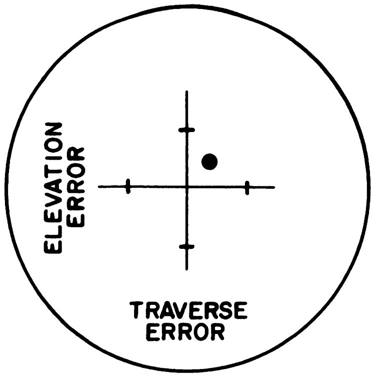
Instantaneous angle tracking accuracy can be observed on the T & E scope (fig. 5-26). Traverse and elevation angle errors are used to deflect a dot horizontally and vertically. Displacement of the dot from the center of the display represents the displacement of the target from the center of the beam.

RHI

The RHI (range height indicator) is a type of scope which provides range and height information (fig. 5-27). It is also known as the type E scan. The fanlike presentation depicts a side view of a height-finder radar's transmissions as they are moved up or down in elevation. The target echo appears as a bright spot with range indicated by the horizontal coordinate and height by the vertical coordinate.

PPI

The ppi (plan position indicator) presentation (fig. 5-28) is the most common



167.894
Figure 5-26.—A T & E scope presentation.

type of scan for range and bearing information. It utilizes an intensity-modulated system with a linear radial sweep for range, and a circular sweep (synchronized with antenna rotation) for target bearing. This scope presents a picture as it would appear if you were looking down on the geographical area that the radar covered.

RADAR COLLIMATION

Radar collimation provides for the parallel alignment of the radar beam axis and optical axis of the radar antenna. Collimation of the tracking or illumination rf axes of a radar to its director (optical axis) is necessary to (1) ensure accurate definition of target position by the director to the fire control computer, and (2) to ensure adequate illumination of the target by a continuous-wave illuminating beam. This can be accomplished by the use of a shore tower on which is located an optical target and a radar horn antenna (fig. 5-29). The horn antenna is connected to rf power measuring equipment and is properly positioned in relation to the optical target. The horn antenna displacement, relative to the optical target, is determined by the relative displacement of the two axes (optical and rf) as measured at the radar.

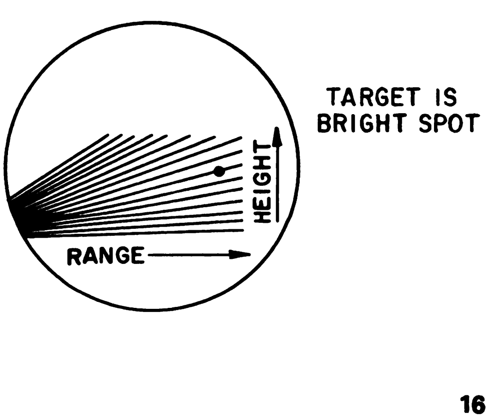


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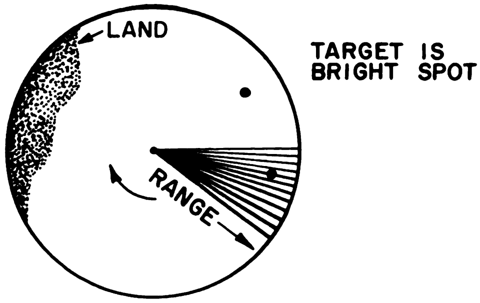
Figure 5-27.—An RHI presentation.



167.895
Figure 5-28.—A ppi presentation.

To check or adjust for parallelism of the two axes, the radar antenna is trained and elevated until the cross hairs of the optical sight intersect the optical target. At this time, maximum rf energy should be directed into the horn antenna as measured by the power measuring equipment. If not, the axes are not collimated and appropriate adjustment procedures should be accomplished. In brief, this requires that one axis be aligned with the other until they are parallel.

Other measurements and alignments also require the use of the shore tower. These are the measurements of angle error sensitivity, the measurement of the angular position of the track transmit axis with respect to the receive axis, and alignment of television cameras.

Collimation requires the use of an antenna/optical array which is mounted on the shore tower. Antenna/optical arrays are also mounted aboard some ships to provide correlation of data to the collimation data when shore towers are not available. The procedures

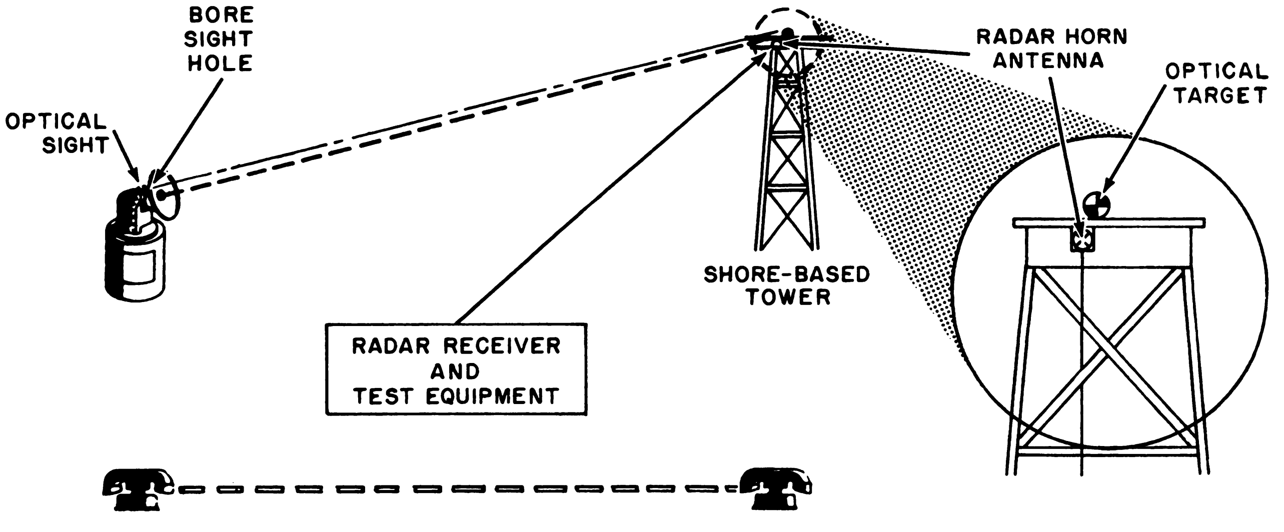


Figure 5-29.—Radar collimation.

are basically the same as those involving shore towers. Allowance, however, does have to be made for the shorter distances that prevail aboard ship.

Step-by-step procedures for accomplishing radar collimation vary between radar installations. You should refer to the applicable radar equipment OPs/TMs for this information.

RADAR COUNTERMEASURES

The operational characteristics of a radar, such as its carrier frequency, transmitted power, pulse width, pulse repetition rate, and scanning rate are radiated into space and therefore can be detected by an enemy. An enemy can use this information to counter the use of our radar. For example, knowing the radar's carrier frequency will enable the enemy to transmit an overpowering signal at that frequency and saturate the radar. If a cw transmission were being used by the enemy, our radar scope would be jammed over the entire range of the radar. This is an electronic countermeasure (ECM) to our radar.

It is essential that a radar be flexible enough to handle all of the countermeasures it can expect.

There are many variations of countermeasures in existence and also numerous new possibilities; therefore, as can be seen from the previous discussion, enemy jamming can offer a radar operator a real challenge. You must not, however, feel that jamming is so intense and effective that nothing can be done about it.

To help you counter the countermeasures, your radar may have many built-in electronic counter-countermeasures (ECCM) circuits. Some ECCM features are based on the known characteristics of a true target echo return and normal scope presentations. Normal echos are approximately equal in duration to the width of the transmitted pulse. The strength of a normal echo is inversely proportional to target range. Circuits in the radar receiver can attenuate or filter out echos with an abnormal length or strength. These antijamming circuits are the fast time constant (ftc), the instantaneous automatic gain control (iagc), and the sensitivity time control (stc).

The ftc circuit changes the RC time constant of one of the stages in the IF amplifier. The time constant is changed so that signals with a longer duration than the transmitted pulse will be differentiated. The differentiated signal is attenuated. Signals of a normal duration are not affected by the ftc circuit.

The iagc circuit provides a negative feedback voltage to some of the stages in the IF amplifier. The feedback voltage is proportional to the echo signal's duration and strength. The negative feedback is increased and the amplification is reduced for longer and larger signals.

The stc circuit makes the gain of the IF amplifier a function of range. An RC circuit is placed in one of the stages of the amplifier so that the gain of the stage will increase exponentially with the output of the RC circuit. At short ranges the gain is minimum; as range increases the gain increases so that at maximum range the gain is maximum. The stc circuit is effective in detecting weak signals in excessive sea return and compensates for the gain needed for weaker distant targets as contrasted with strong nearby targets.

Many fire control radars have a passive angle track (PAT) mode. For a target that is using an active jammer covering the pulse radar frequency at a power level sufficient to mask the return echo, this passive track mode can be used. In passive track, the radar angle tracks the jamming source but cannot track in range since the target return is masked. If target range from some other source is not available for input, the computer uses some preselected value of range.

It has been found that quite often, when encountering jamming, even a very slight amount, an inexperienced operator becomes confused and frustrated because of an inability to handle the situation, and quite early in the game wants to "throw in the towel."

Remember, during jamming you are not expected to have all target information all of the time as when in normal operation. With modern weapon systems a kill can still be obtained even with only partial target information.

Recognizing and identifying radar countermeasures is over half the battle. If you have succeeded in accomplishing this, you have eliminated the elements of confusion and surprise which the enemy has tried to force on you. You are then able to cope more efficiently with the countermeasures being applied, and you should be able again to gain useful information from your fire control radar.

SAFETY

There are safety and health hazards involved with operating and maintaining high power radars. These hazards result from high levels of rf radiation, x-ray emissions and the necessity of "working aloft."

RF RADIATION HAZARDS

Radar peak power may reach a million watts or more. Rf radiation hazards exit in the vicinity of radar transmitting antennas. These hazards are present not only in front of an antenna but also to the sides and sometimes even behind it due to spillover and reflection. At some frequencies, exposure to excessive levels of radiation will not produce a noticeable sensation of pain or discomfort to give warning of injury. If you suspect any injury, see your ship's doctor or corpsman. Be sure to acquaint yourself with the actual radiation hazard zones of the radars on your ship.

The following precautions should be observed to ensure that personnel are not exposed to harmful rf radiation:

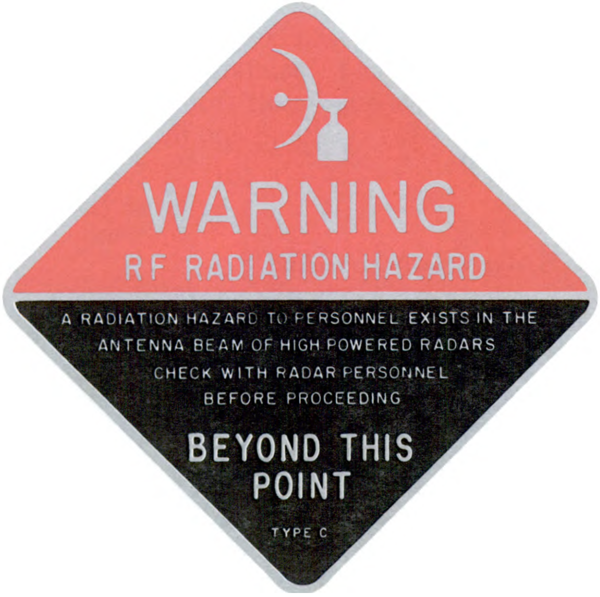
- Visual inspection of feedhorns, open ends of waveguides, and any opening emitting rf energy will not be made unless the equipment is definitely secured for that purpose.

- Operating and maintenance personnel shall observe all rf radiation hazard signs posted in the operating area.

- All personnel shall observe rf radiation hazard (radhaz) warning signs (fig. 5-30) which point out the existence of rf radiation hazards in a specific location or area.

- Ensure that radiation hazard warning signs are available and used.

- Ensure that those radar antennas which normally rotate are rotated continuously while radiating, or are trained to a known safe bearing.


WARNING
RF RADIATION HAZARD
A RADIATION HAZARD TO PERSONNEL EXISTS IN THE ANTENNA BEAM OF HIGH POWERED RADARS
CHECK WITH RADAR PERSONNEL BEFORE PROCEEDING
BEYOND THIS POINT
TYPE C

40.67(76)

Figure 5-30.—Sample radhaz sign.

- Train and elevate non-rotating antennas away from inhabited areas (ships, piers, and the like) while radiating.

- The use of dummy loads shall be employed where applicable as a load for equipment during testing or checkout.

X-RAY EMISSIONS

X-rays may be produced by high voltage electronic equipments. X-rays can penetrate human tissue and cause damage of a temporary or permanent nature. Unless the dosage is extremely high, there will be no noticeable effects for days or weeks, or even years after the exposure.

The sources of these x-rays are usually confined to magnetrons, klystrons, and crt's. Where these types of components are used, personnel should not linger near any equipments on which the equipment covers have been removed. Klystrons, magnetrons, rectifiers, or other tubes which employ an excitation of 15,000 volts or more may emit x-rays out to a few feet, thus endangering unshielded personnel standing or working close to the tubes.

When performing maintenance on x-ray emitting devices, the following precautions should be taken:

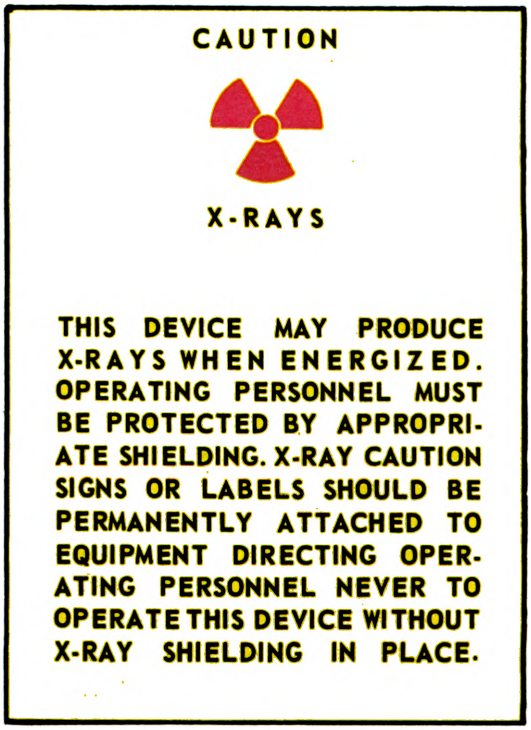
- Observe all warning signs (fig. 5-31) on the equipment and all written precautions in the equipment tech manuals.

- Unless called for in the tech manual, do NOT bypass interlocks that permit the servicing of operating equipment with the x-ray shield removed.

- Be sure to replace all protective x-ray shielding when servicing is complete.

WORKING ALOFT

There is another hazard inherent to working on radar antennas. As most radar antennas are


CAUTION
X-RAYS
THIS DEVICE MAY PRODUCE X-RAYS WHEN ENERGIZED. OPERATING PERSONNEL MUST BE PROTECTED BY APPROPRIATE SHIELDING. X-RAY CAUTION SIGNS OR LABELS SHOULD BE PERMANENTLY ATTACHED TO EQUIPMENT DIRECTING OPERATING PERSONNEL NEVER TO OPERATE THIS DEVICE WITHOUT X-RAY SHIELDING IN PLACE.

167.896

Figure 5-31.—X-Ray caution label.

located on masts or on other parts of the upper super-structure, you will be going aloft to work on them.

Hazards while working aloft include death or injury from falling, asphyxiation from stack gasses, and electric shock (either from the equipment being worked on or from induced voltages in guy wires and other ungrounded conductive materials due to radiation from radio and radar antennas). Also included are overexposure to radiation from high-powered radar antennas, contact with rotating or oscillating antennas or other moving machinery, and overexposure to inclement weather conditions.

In addition to the danger from electric shock due to energized equipment and induced voltages, there may also be a shock hazard due to static charges. Static charges are caused by electrically charged particles that exist naturally in the air. Under certain conditions these charged particles will collect on metallic objects such as wire antennas and produce a shock hazard. Grounding the objects concerned will eliminate the hazard. Shocks from static charges will not cause direct harm to the individual, but any unexpected shock while aloft may cause a person to fall.

Before going aloft, you must obtain permission from the officer of the deck, and all transmitters and machinery in the vicinity of the work area must be secured and tagged. Permission must also be obtained from the engineering officer to ensure that boiler tubes will not be blown or boiler safeties set during the time the work is being done aloft. If in port or at anchor, you must also obtain permission from the OOD of any ships moored alongside. Notify these ships when work is completed.

You must wear an approved parachute-type safety harness (fig. 5-32) at all times when working aloft. (The lineman-type safety belt is no longer authorized for Navy use.) Safety harnesses must be checked periodically in accordance with the Planned Maintenance System. Tools to be used on the job should be placed in a canvas bag and hauled up with a line to the job location. To guard against dropping tools and seriously injuring someone, it is recommended that the tool being used be tied to the safety harness with a piece of line.

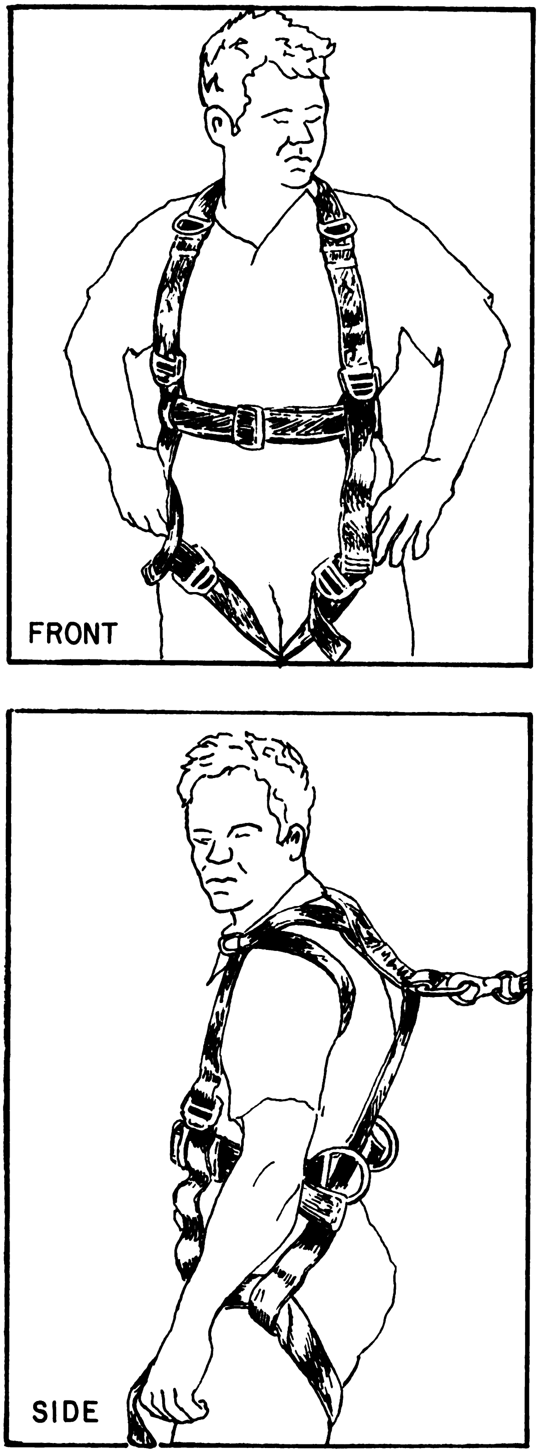


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Figure 5-32.—Parachute-type safety harness.

CHAPTER 6

SUPPORT SYSTEMS

When you think of weapons system equipment, you probably envision complex electronic circuitry, computers, radars, control consoles, and other sophisticated equipment. It may be easy to forget that equipment of this nature relies on other systems (referred to as support systems) that are not normally thought of in terms of weaponry. These support systems include electrical power, dry air, and liquid cooling systems. Without the support of these systems, our weapon systems could not function.

It is necessary, therefore, that you be aware of these support systems and understand their relationship to your weapons system equipment.

ELECTRICAL POWER

As an FTM, part of your routine duties will be to energize certain fire control equipment. This may occur every morning for daily tests or after a lengthy period of shutdown time for maintenance.

There is nothing quite as frustrating as not being able to "light off" your radar because of a missing power input. If you know where the power is supposed to come from, maybe you can help to restore it.

Let us now look at a typical ship's power distribution system. (The power system on your ship is probably similar in many ways.) We will briefly mention the overall power distribution system and then discuss the areas that are closely related to your equipment.

POWER DISTRIBUTION SYSTEM

Most a.c. power distribution systems in naval vessels are 450-volt, 60-hertz, 3-phase, 3-wire, ungrounded systems. The a.c. power distribution system consists of the power plant, the means to distribute the power, and the equipment which uses the power (fig. 6-1).

The power plant is either the ship's service turbine generator or the emergency diesel generator.

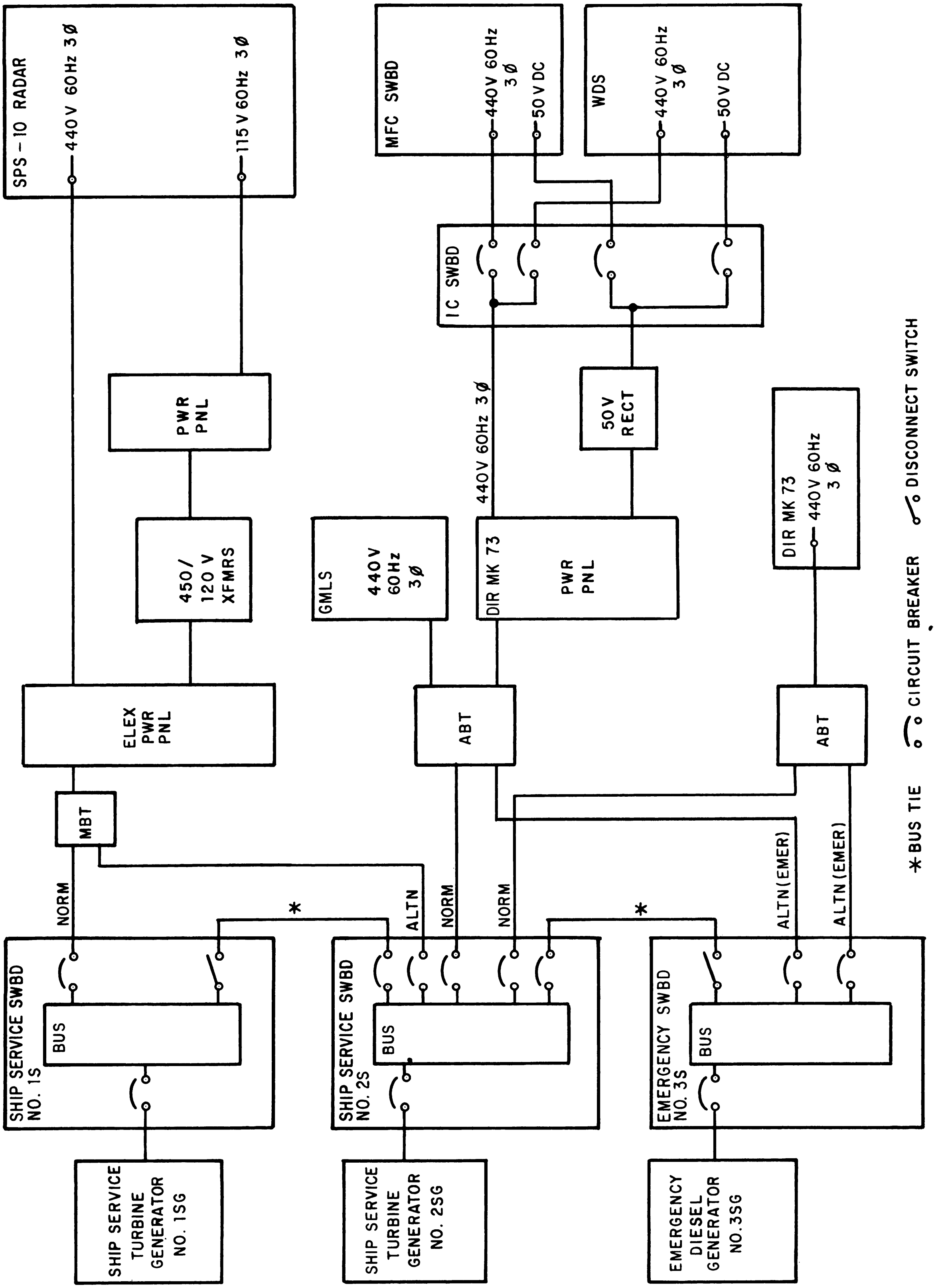
The power is distributed through the ship's service distribution switchboards and power panels. Some large ships also use load centers, which function as remote switchboards.

Power is used by any equipment which requires electrical power for its operation (lights, motors, director power drives, radar equipment, weapon direction equipment, computers, etc.).

EMERGENCY POWER

In the event of failure of the ship's service distribution system, the emergency power distribution system supplies an immediate and automatic source of electric power to a limited number of selected loads that are vital to the safety of the ship. This system includes one or more emergency diesel generators and switchboards. The emergency generator is started automatically when a sensor detects the loss of normal power.

The operation of the ship's service generators, the emergency generators, and distribution switchboards is the responsibility of



167.897

Figure 6-1.—60 Hz distribution (partial).

the ship's engineers (machinist's mates, electrician's mates, enginemen, etc.). You will not become involved within this area of responsibility. There will be times, however, when you'll be concerned because your electrical power requirements are not being met, and, for that reason, you will request that the appropriate engineering personnel provide you with assistance. Needless to say, it will be to your advantage if you can communicate in terms with which the engineering personnel are familiar.

BUS TRANSFER EQUIPMENT

Bus transfer equipment is installed on switchboards, at load centers, on power panels, or on loads that are fed by both normal and alternate and/or emergency feeders (fig. 6-1). Either the normal or alternate source of the ship's service power can be selected. Emergency power from the emergency distribution system can be used if an emergency feeder is also provided.

Automatic bus transfer (ABT) equipment is used to provide power to vital loads, while nonvital loads can be fed through manual bus transfer (MBT) equipment. For example, the interior communications (IC) switchboard is fed through an ABT, whose alternate input is from the emergency switchboard. A search radar might be fed through an MBT.

POWER DISTRIBUTION

Power distribution is directly from the ship's service switchboards to large and important loads, such as missile launchers and missile directors on all ships so equipped (fig. 6-1). Distribution to other loads is through power distribution panels and, if applicable, load centers.

IC SWITCHBOARD

The IC switchboard is the nerve center of the interior communications system. All interior communication and some fire control circuits, including fire control electronic circuits, are energized through the IC switchboard. Relay supply voltages, synchro excitation, and some 400 Hz power pass through this switchboard. Some of these supply voltages may be routed from the IC switchboard directly to the weapons equipment. Most of them, however, are also routed through the missile fire control switchboard. Larger ships usually have two IC switchboards (one forward and one aft), while smaller ships have one centrally located IC switchboard.

60 HZ

Many of the bigger loads in the weapon system use 440 V, 60 Hz, 3ϕ power as a power source (fig. 6-1). This supply is also sent to transformers for conversion to 115 V, 60 Hz, 3ϕ power for distribution where needed. Additionally, it is used an an input to the 50 V d.c. rectifier at the IC switchboard. The 50 V d.c. rectifier output is distributed throughout the weapon system as a relay supply voltage.

400 HZ

The 440 V, 400 Hz, 3ϕ power is made up in motor generator (MG) sets that are fed by the 440 V, 60 Hz power (fig. 6-2). The 400 Hz supply is the primary source of power for the weapon system. Distribution is primarily through the missile fire control switchboard via the IC switchboard. Besides the 440 V, 400 Hz signal, 115 V, 400 Hz power from regulated and unregulated transformers is supplied throughout the weapon system. In some systems the 115 V, 400 Hz power is used as the input to a voltage regulator for generation of a 115 V, 400 Hz precision supply.

MISCELLANEOUS POWER

There are many other supply voltages used in the missile weapon systems and subsystems. They are usually used as reference voltages for specific functions. For example, 12 V a.c. is used as a reference for fire control designation quantities in some systems.

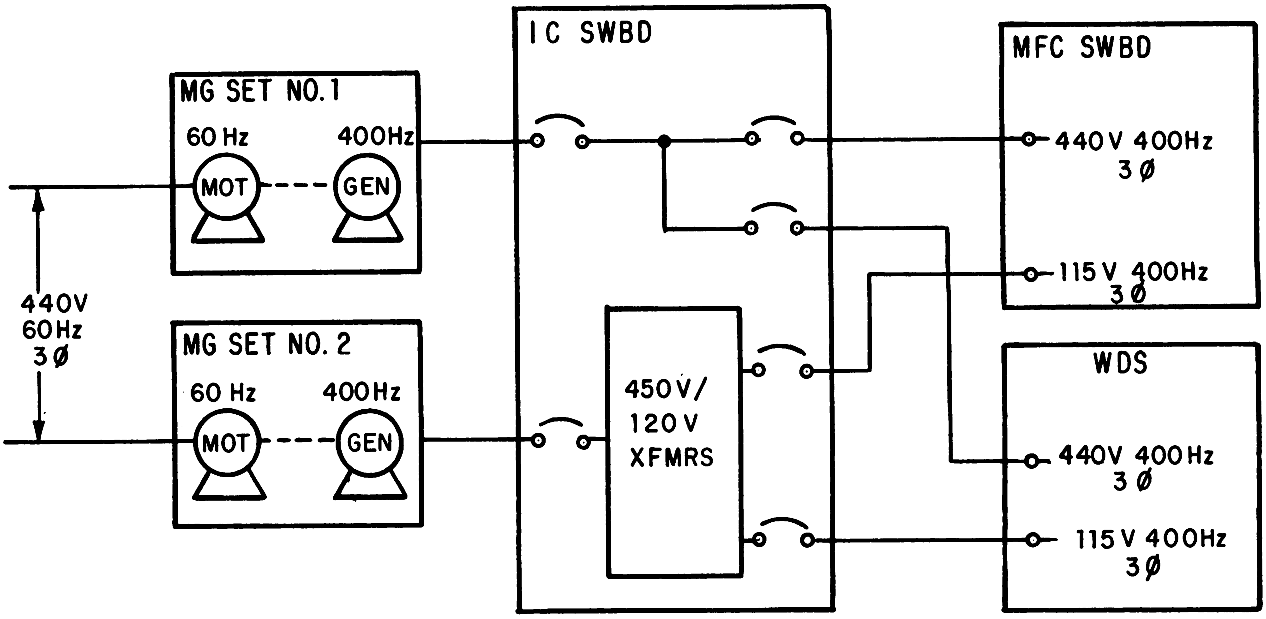


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Figure 6-2.—400 Hz distribution (partial).

The thing to do when you are missing a certain power input to your equipment is to work backward from the load to the source. Usually, the power panels and bus transfer units that feed the equipment are located in close proximity—possibly in the same space or outside in the passageway.

Keep in mind that many suspected casualties have been corrected merely by restoring an inconspicuous power input or signal reference, sometimes after hours of troubleshooting.

AIR SYSTEMS

Some parts of missile weapon system equipment are dependent on inputs of dry air for proper operation. The weapon system's dry air is normally supplied by the ship's central dry air system. This system produces high-pressure (hp) air and low-pressure (lp) dry air for distribution to user equipment. As an FTM, your user equipment will most likely be a search or a fire control radar.

HIGH-PRESSURE AIR

The ship's service compressors supply the high-pressure air at 3,000 or 4,500 psi. In the missile weapon system, it is used only for the launching system's dud ejection system, where applicable. In an emergency, the high-pressure air, reduced in pressure, can be used to supplement the low-pressure air supply through the HP/LP cross-connect.

LOW-PRESSURE DRY AIR

A central dry air system is shown in figure 6-3. It includes the low-pressure air compressors and the Type I (refrigerant) dehydrators, which dry all low-pressure air supplied to the vital services air main. Also included are the priority valve, which automatically isolates vital users from nonvital users when required, and the ship service low-pressure air main, which supplies nonvital users.

Vital lp air users are defined as equipment or services essential to optimum ship performance. Examples include the engineroom and boiler room controls and the electronics dry air branch.

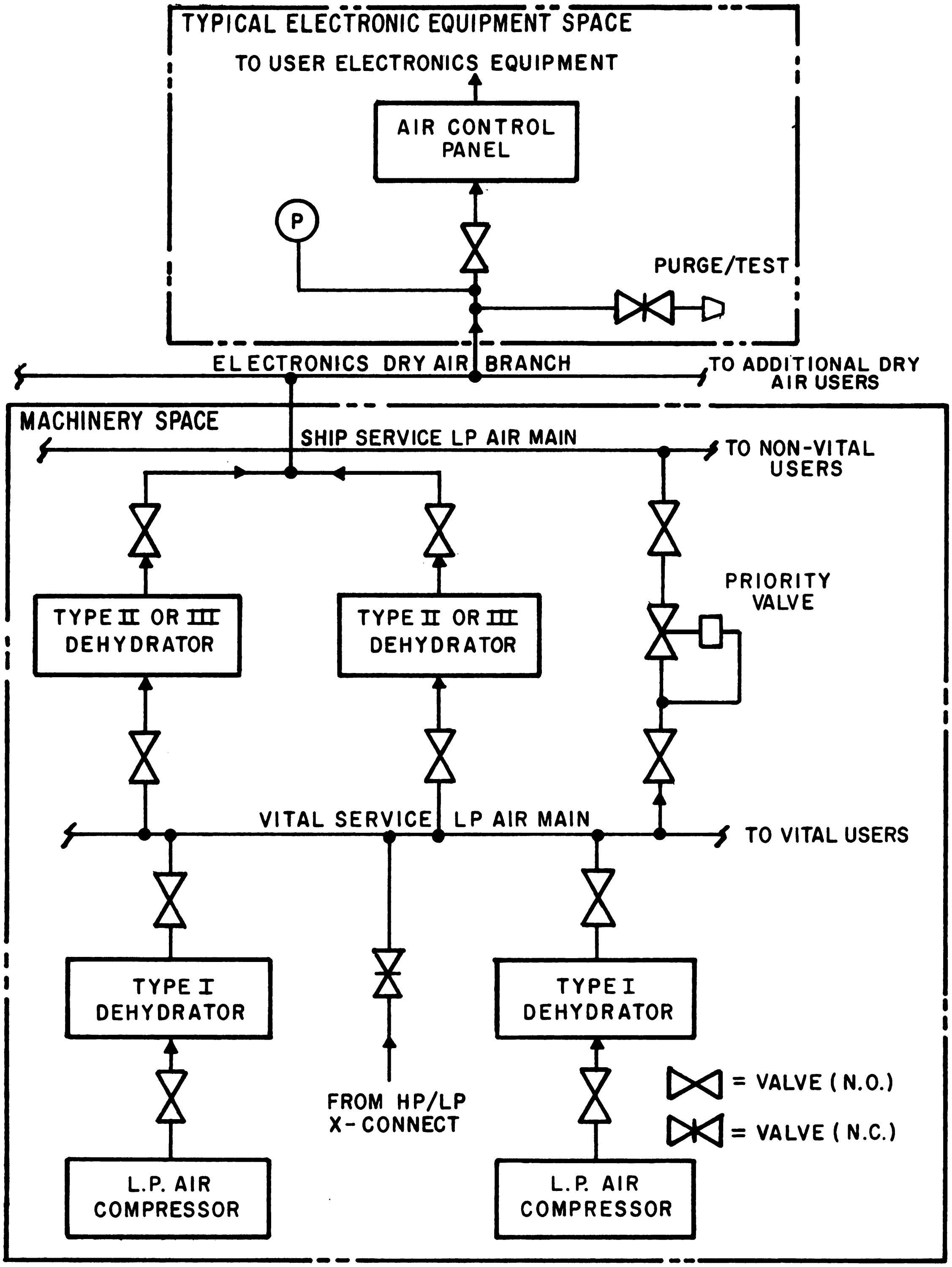

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Figure 6-3.—Typical lp air system layout.

Examples of nonvital air users are pneumatic tools, laundry equipment, and gage test panels. Special attention is necessary for the electronics dry air branch of the vital services main because of its requirement for additional dehydration of low-pressure air.

Electronics Dry Air Branch

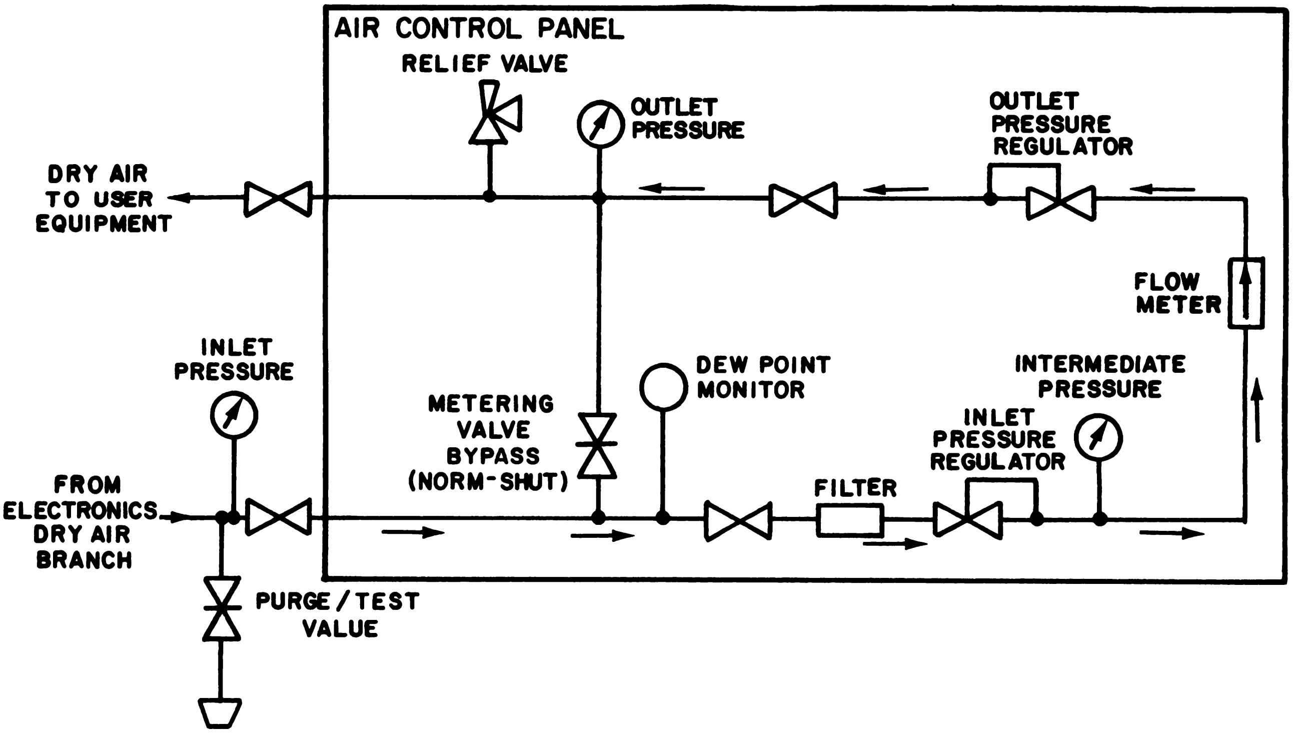
The electronics dry air branch is fed from the vital services main via the Type II (desiccant) or Type III (combination refrigerant and desiccant) dehydrators (fig. 6-3). The purpose of the electronics dry air branch is to provide an effective electronic equipment pressurization system with a minimum of material. Electronic components, such as waveguide, couplers, and cavities, operate at radio frequencies. They require dry air pressurization to prevent arcing and internal corrosion. The electronics dry air branch must satisfy the dry air pressurization requirements of the electronic user equipment. Dry air of less than the required specifications will degrade performance and may necessitate major repairs, overhaul, or replacement of expensive electronic components.

Air Control Panel

The dry air distribution system delivers dry air to each user equipment's air control panel (fig. 6-3). The air control panels are used to control and regulate the dry air pressure to that required by the electronic user equipment.

The air control panel (fig. 6-4) provides a means of monitoring the dry air supply to the user equipment. The type of control panel used varies, depending on the outlet pressure and flow rate required.

There are provisions for monitoring the dew point (moisture content) and the flow of the lp dry air at the air control panel. Also, the dry air pressure can be monitored at the input to the control panel, at the input to the flow meter



167.900

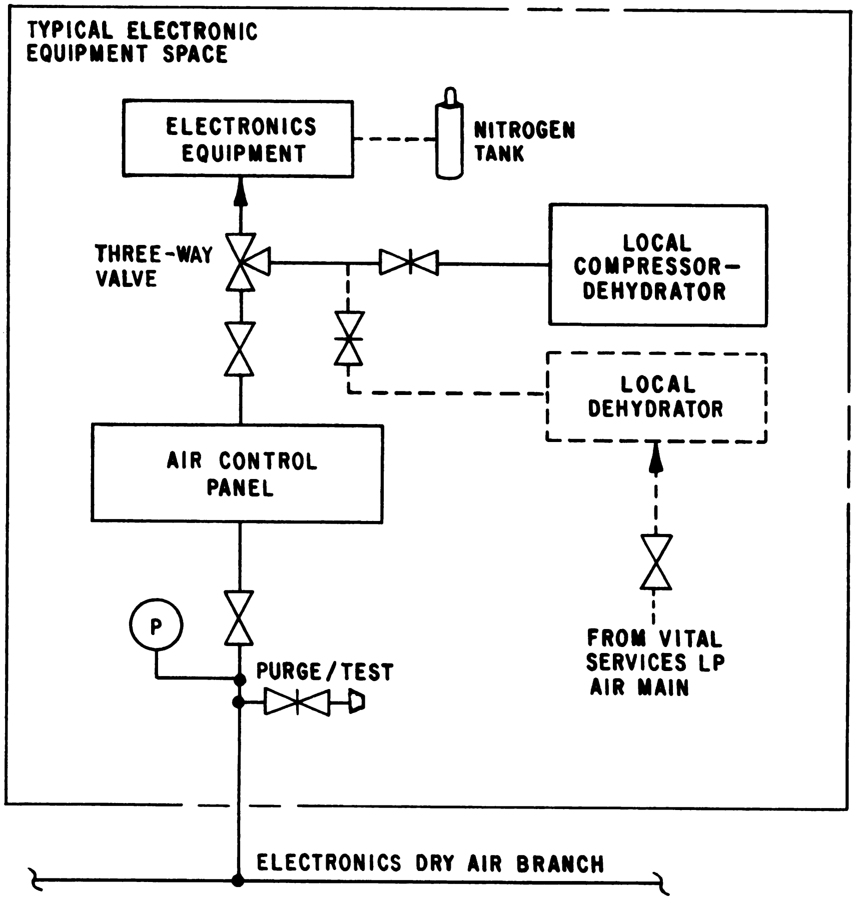
Figure 6-4.—Air control panel flow diagram.

(whose accuracy is calibrated at a certain pressure), and at the output of the control panel. A filter is installed to trap particles that affect proper pressure regulation. A metering valve bypass and a pressure relief valve are provided in case of malfunctions. The metering valve bypass permits manual control of air pressure to the user equipment.

Electronic Equipment Dehydrators

Dehydrators or compressor-dehydrators are supplied as part of various radars. Many of them were provided prior to installation of properly configured central dry air systems. These are intended for emergency use in the event of the failure of the central dry air system. In a typical configuration (fig. 6-5), the outlet air from the local dehydrator is connected between the air control panel outlet and the user equipment or radar by a three-way valve.

Local dehydrators depend on the ship's lp air for an inlet supply, while the local compressor-dehydrators can operate independently of the ship's air supply. Some units of electronic equipment that have local dehydrator units are pressure interlocked within the dehydrator unit. When the outlet air pressure is below a set value, the interlock prevents the equipment from going to a full OPERATE condition. When the central dry air system is used, the pressure interlock is bypassed.


TYPICAL ELECTRONIC EQUIPMENT SPACE
ELECTRONICS EQUIPMENT
NITROGEN TANK
THREE-WAY VALVE
LOCAL COMPRESSOR-DEHYDRATOR
LOCAL DEHYDRATOR
AIR CONTROL PANEL
P
PURGE/TEST
FROM VITAL SERVICES LP AIR MAIN
ELECTRONICS DRY AIR BRANCH

167.901

Figure 6-5.—Typical local dehydrator interface.

Some radars have a provision for connecting a tank of nitrogen as an emergency source in place of dry air. Special safety precautions must be exercised when handling compressed gases because of the possibility of explosion. Nitrogen gas does not support life, and when released in a confined space will cause asphyxia.

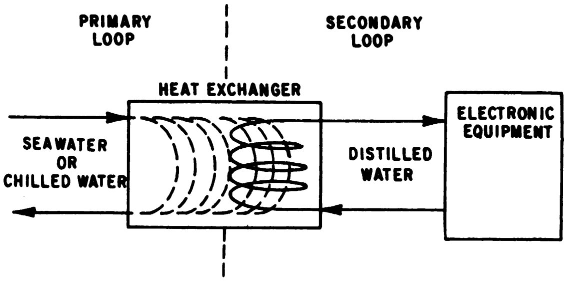
COOLING SYSTEMS

Liquid cooling systems are vital to the proper operation of shipboard electronic and weapons control equipment. Because of their importance, these cooling systems must be reliable and readily available.

For an electronic water cooling system to operate satisfactorily, the temperature, quantity, purity, flow and pressure of the water must be controlled. This control is provided by various valves, regulators, sensors, meters, and instruments which measure the necessary characteristics and either directly or indirectly generate the system regulation required.

The liquid cooling system consists of a seawater or a chilled (fresh) water section that cools the distilled water circulating through the electronic equipment. The main components of the system are the piping, the valves, the regulators, the heat exchangers, the strainer, the circulating pumps, the expansion tank, the gages, and the demineralizer. Other specialized components are sometimes necessary to monitor cooling water to the electronic equipment.

A typical liquid cooling system (fig. 6-6) is composed of a primary loop and a secondary loop. The primary loop provides the initial source of cooling water and the secondary loop transfers the heat load from the electronic equipment to the primary loop. A source of cooling water for the primary loop is either seawater from a seawater supply or chilled water from the ship's air conditioning plant. The cooling water used in the secondary loop is distilled water from the ship's evaporator. Ultrapure systems are maintained by a demineralizer and use double-distilled water obtained through the Navy Supply System.



167.902
Figure 6-6.—Liquid cooling system, block diagram.

TYPES OF COOLING SYSTEMS

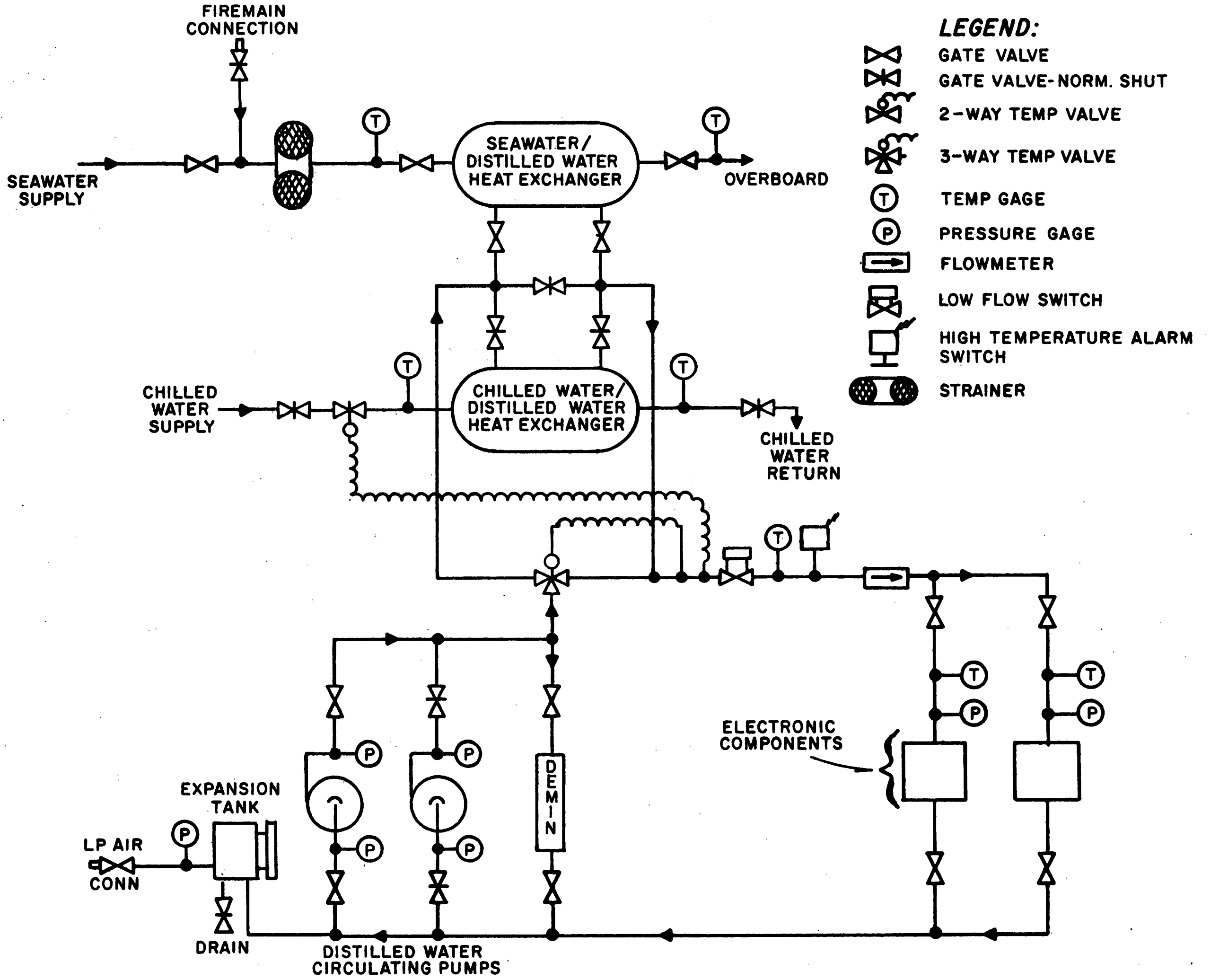
Liquid cooling systems vary from ship to ship with respect to the number and type of electronic equipment (radar, sonar, NTDS) that require cooling water, the system components, and the cooling water employed. The basic types vary according to the source of cooling water for the primary loop. Some ships may have more than one cooling system and these may be of varying types.

The general arrangement of a liquid cooling system is shown in figure 6-7. This particular type has a seawater/distilled water heat exchanger and a chilled water/distilled water standby heat exchanger. Other basic types have either seawater or chilled water inputs to both heat exchangers.

PRIMARY COOLING SYSTEM

The primary cooling system or loop (fig. 6-7) consists of a seawater supply, a strainer that removes debris, gate valves, and a heat exchanger. The seawater may be supplied from a seawater pump, often referred to as the ordnance cooling pump, or from the ship's firemain. There may be a low flow switch in the seawater line that activates alarms in the electronic spaces concerned.

A duplicate heat exchanger is installed parallel to the main heat exchanger and is maintained in standby in the event of a malfunction in the main heat exchanger. As previously indicated, the standby heat exchanger in our example uses chilled water.



274.86

Figure 6-7.—Liquid cooling system, typical arrangement.

SECONDARY COOLING SYSTEM

The secondary cooling system or loop is designed to transfer the heat from the electronic equipment being cooled to the primary cooling system. It usually consists of a distilled water circulating pump, a demineralizer, a 3-way temperature controlled valve, an expansion tank, the electronic equipment being cooled, and the heat exchanger previously mentioned. A flowmeter, a low-flow switch, a high-temperature switch, and their associated alarms may also be included.

Some electronic coolant systems have an electric coolant heater. This allows the coolant and electronic equipment to reach operating temperature and stabilizes temperature-sensitive components. The electric coolant heater is usually energized by a preheat signal.

SYSTEM OPERATION

Cool primary system water flows through the tubes of the heat exchanger. As secondary system coolant flows around these tubes, heat that was absorbed from electronic components is transferred to the primary system water. A 3-way temperature valve with a sensor in the distilled water loop is installed to bypass distilled water around the heat exchangers to control the distilled water temperature.

When chilled water is used as the primary supply, a two-way temperature valve is used to regulate the flow of chilled water through the heat exchanger. This action, in response to a sensor in the distilled water loop, helps maintain the required distilled water temperature.

The flow rate of the distilled water is monitored by a flowmeter after it passes through low-flow and high temperature alarm switches. The cooled distilled water is supplied to the various heat exchangers in the electronic equipment.

Either the liquid-to-air or the coolant-jacket type of heat exchanger is used in the electronic equipment. An example of the liquid-to-air heat exchanger is an equipment cabinet fan which circulates air across a heat exchanger. Coolant-jackets may be found around klystrons or pulse-forming networks.

From the electronic equipment, the distilled water is returned to the suction side of the circulating pump. On those systems where high-purity distilled water is required, a demineralizer is installed in a bypass line around the circulating pump. A flow regulator is designed to pass approximately 5 percent of the total system volume through the demineralizer each hour. The demineralizer is designed to remove solids, dissolved metals, carbon dioxide, and oxygen. In addition, a submicron filter is installed downstream of the demineralizer to prevent the carryover of chemicals into the system and to remove remaining impurities.

An expansion tank is provided in the distilled water system to compensate for changes in the coolant volume caused by thermal expansion. The expansion tank also provides a source of makeup water in the event of a system leak. The tank is installed in a branch line connected to the suction side of the circulating pump. When used as a gravity tank, the tank is located above the highest point in the system and vented to the atmosphere. Otherwise, the expansion tank is located in the vicinity of the circulating pump and charged with air pressure to achieve the required distilled water return line pressure.

Pressure gages and temperature gages provide monitoring of component and system performance. A high-temperature switch, a low-flow switch, a low-level switch, and a low-purity alarm provide remote monitoring of the cooling system operation. The devices are usually connected to remote indicators (visual and audible alarms) or to interlocks that deenergize the electronic equipment.

WATER PURITY

One of the most significant improvements in the operation of electronic cooling water systems can be achieved by using water of the appropriate purity. All electronic cooling water systems use distilled water which flows through the equipment in the secondary cooling loops. The required purity of this water coolant will vary, from normal ship's distilled water to "ultrapure" water, depending on the requirements of the electronic equipment.

Before water is introduced into the cooling system, a determination must be made, using the appropriate technical manuals, regarding the quality of water used versus the purity of water required. Once the correct water has been introduced into the system and the desired purity attained, the purity must be monitored to assure that it stays within the requirements of the equipment. Most purified electronic cooling systems have meters installed which can be checked to determine the purity of the water. In addition to the routine observation of these meters and in systems where no meters are installed, a separate test of the water itself should be conducted periodically to check on the water purity and the accuracy and operation of installed meters.

The impurities found in distilled water are usually in the form of dissolved solids. The amount of dissolved solids in the distilled water can be determined by measuring the conductivity (micromhos/cm) or its reciprocal, resistivity, (megohms/cm) of the distilled water. The purity meter on the demineralizer measures the resistivity of the water in megohms/cm. The resistivity can be converted to conductivity by taking the reciprocal of the resistivity. The ideal condition is one of high resistivity which indicates that the demineralizer is maintaining a high degree of purity.

Although the purity required by different kinds of equipment varies, it should be noted that potable (drinking) water or treated boiler water is not to be used in any electronic cooling water system. (Even though the potable water comes from the distilling plant, its treatment with cholorine makes its use in the cooling system unacceptable.) Only distilled water taken directly from the ship's evaporators is suitable. In addition, it must be realized that additives, such as rust preventatives and antifreeze, are not normally used in these electronic cooling systems, except where specifically authorized in the appropriate technical manuals for that particular system.

CHAPTER 7

ADMINISTRATION

It may seem strange to include a chapter on administration for FTMs in this pay grade, but as a member of the weapons department, you are a partner in its administration. True, most of your working day is spent on a particular piece of equipment that is but a part of the entire weapon system. Therefore, you probably think of yourself as being subjected to administration rather than being a part of it. Actually, it is your work, ability, and training, plus your equipment, that is being administrated; and you have some say in the setting of administrative policies.

The operational and maintenance policies on your equipment are based in part on data obtained from the records and reports that you make. Thus, administration is a tool to aid you, and is well worth the paperwork involved. The help you receive from administration is not always clear and the paperwork is sometimes set aside or forgotten due to someone's haste. When this happens, everyone loses because something is taken away from the organization.

Your big job is to keep fire control equipment in top working order. To help you do this, the Navy provides many publications (pubs) and other written material relating to the maintenance task. In return, the Navy requires you to provide written reports on how well you are maintaining your equipment. By a roundabout way there is a constant flow of information between you and the Navy, principally between you and the Naval Sea (NAVSEA) Systems Command.

Your information may leave your ship in the form of a letter or report and be processed by a machine or an individual in NAVSEA. The information you have supplied may trigger some kind of corrective action in NAVSEA, or it may be filed away for future use.

To illustrate, let's assume you have sent in five failure reports on one relay. You may think that this recurring casualty happens only in your equipment, but 10 other ships have also sent similar reports to NAVSEA. An engineer in the guided missile fire control system section in NAVSEA notices a failure pattern and analyzes the relay circuit. The engineer detects a faulty circuit design. He then redesigns the circuit to correct the relay failure. Finally, the engineer writes instructions on how to rewire the existing relay circuit and sends these instructions to all ships that have the same model of fire control equipment that you have. These instructions are called Ordnance Alterations (ORDALTS). If the circuit change is not complicated or requires minor changes to equipment, you will make the circuit alterations. Complicated and major changes require technical assistance from fleet support groups. Thus, a correspondence loop has been completed, or in Navy jargon, there is "feedback." This feedback loop system is very important. Any break in the loop destroys the effectiveness of the system. Do not be the one to break it.

Some of the bookkeeping chores you will be involved with are part of your military duties and therefore are covered in the current revision of *Military Requirements for Petty Officer 3 &2*, NAVEDTRA 10056. The chapters of particular interest to you at this time are the chapters on "Supply" and "The 3-M System."

PUBLICATIONS

There are many publications used in the proper maintenance of fire control equipment. Technical publications issued by various systems commands and other departments of the Navy are sources of important information for every person in the Navy. Publications issued by the Naval Sea Systems Command, (NAVSEA and the old NAVORD and NAVSHIPS pubs) and Naval Supply Systems Command (NAVSUP pubs) are the main concern of missile fire control technicians. The most important pubs from these sources that you should be familiar with are discussed in this chapter.

ORDNANCE PAMPHLETS

The main source of technical information on the operation and maintenance of ordnance is the Ordnance Pamphlet (OP). NAVSEA publishes these technical manuals, each under its own OP number. (Some older OPs may still have the original NAVORD title.) They may be prepared by some other naval activity, by the manufacturer, by a commercial specialist in such publications, or by NAVSEA itself. Surface missile system (SMS) OPs are divided into two categories: system OPs and equipment OPs).

System OPs provide the information necessary to operate a shipboard surface-to-air guided missile weapon system in all modes. Information for performing routine maintenance and fault isolation to the level of a distinct functional area within an equipment is also provided.

Equipment OPs provide all the information required by Navy personnel to understand, operate, and maintain individual items of equipment. Equipment OPs are organized as follows:

- Safety summary
- Introduction
- Physical description
- Functional description
- Circuit theory
- Operation
- Maintenance
- Troubleshooting
- Parts list

Another category of OPs that you will find of interest are general OPs. General OPs take up a subject matter AREA rather than a specific item of ordnance equipment. Such OPs, of course, do not follow the system and equipment OP structure. But they are written and indexed to serve as a reference book for instruction and training. A good example of this type of OP is NAVORD OP 3000, Weapons Systems Fundamentals. This introduces and explains the basic principles of weapons and weapons system components.

The OP may someday be a thing of the past. New and revised pubs are now issued as technical manuals, and will be described shortly.

ORDNANCE DATA

Ordnance Data publications (ODs) are limited-use technical publications covering a wide range of subjects. These may include information concerning installation and overhaul procedures and manufacturer's test and alignment data.

TECHNICAL MANUALS

Technical manuals (TMs) issued by NAVSEA (and formerly NAVSHIPS) provide information that is needed for the proper installation, operation, and maintenance of electrical and electronic equipment. Search radars and system support equipment are sustained by this type of pub.

TMINS

Currently, the Navy is converting to a new system of identifying technical publications. The new system is an alphanumeric system referred to as the "Technical Manual Identification Numbering System (TMINS)." It is being developed as a standard method of numbering and will apply to all technical pubs (OPs, ODs, TMs, etc.). As such, it will do away with many of the problems that now exist in the areas of shipping and data processing.

The new system gives all the information needed to identify the publication. Figure 7-1 shows the format being used and gives an example. The example is translated in the following manner:

S	Cognizant systems command (NAVSEA)
W221	Established NAVSEA code used to identify Gun Fire Control Systems
D3	Arbitrary code chosen to identify the Mk 68 Mods 3, 4, and 6
MMI	Abbreviation for Maintenance Manual (intermediate level)
01	Single volume manual or the first of a multi-item set
A	Change 1 (B = change 2, C = change 3, etc.). "O" denotes a new book or a new revision
/MK 68 -3/4/6	Noncoded mark numbers

Only new or newly revised technical publications are being assigned the new numbers. It may be years before all of the Navy's publications have been converted over to the new system. Until then, you will continue to see technical publications identified in different ways.

PUBLICATION CHANGES

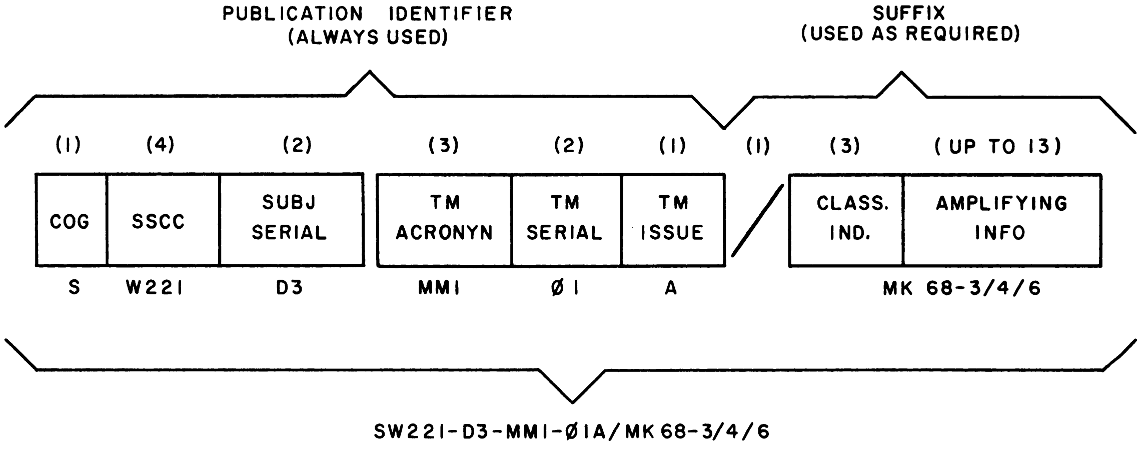
A constant review of NAVSEA publications takes place. This is done to correct errors and keep them up to date. A vast amount of data on the operation, performance testing, and maintenance of ordnance equipment is received and processed routinely by NAVSEA. When new methods are developed after a pub has been issued, a change to the pub is issued.

When changes are made to ordnance publications, an entire page or section of the pub is changed. The change pages are provided, along with a change guide.

Changes to a pub are numbered consecutively and should be made in that order. When the changes to a pub become too extensive, a revised edition is issued. The indexes of ordnance publications list the latest revision and the number of changes to each pub.

Types of Changes

Message Changes (MC) are issued when urgently required with respect to hazardous types of problems. They are concerned with such subjects as personnel, equipment, and ammunition. Message changes provide NAVSEA with the means to rapidly make known urgent



167.903

Figure 7-1.—TMINS Example.

change information. If you come in contact with this type of change, recognize the fact that it points to a hazardous condition, and enter the change at once.

Formal Changes (CH) are formal replacement pages for technical manuals issued to cover major design changes such as ORDALTs and SHIPALTs (alterations to nonordnance equipment). They also incorporate improvements or an accumulation of corrections, including all outstanding message changes, SMS technical bulletins, and actions resulting from deficiency feedback procedures.

A change guide provides detailed step-by-step instructions for entering a change. If you become involved in updating ordnance publications, accomplish changes as rapidly as possible and carefully follow the instructions of the change guide. You must also ensure that the change applies to your particular equipment configuration.

SMS TECHNICAL BULLETINS

SMS technical bulletins are an important source of information, containing up-to-the-minute data on a particular weapon system. For example, the TERRIER, TARTAR, and Basic Point Defense systems each have a bulletin source of data. The bulletins serve the need for the rapid spread of official NAVSEA approved material, such as new or revised test procedures, troubleshooting techniques, methods of alignment and adjustment, and other technical information on a system. The information is obtained from fleet commands and units, shore activities, and civilian contractors. The bulletins are then distributed to all activities concerned with the weapons system. Later this information may be incorporated into the pubs on the system and may result in an alteration to the weapons system.

Technical bulletins may call attention to technical problems and to the specific procedures in related technical manuals which, if followed carefully, should greatly reduce or eliminate these problems. A technical bulletin may note a problem area for which a solution is being developed, and which will be covered in an official pub change as soon as the solution has been determined.

Technical bulletins will not be used in place of technical manuals or PMS documentation changes, nor shall they be used in place of an ORDALT to direct engineering changes or equipment alterations.

DEFICIENCY CORRECTIVE ACTION PROGRAM

The Deficiency Corrective Action Program (DCAP) provides a means of communication between the fleet technicians and their civilian counterparts, the engineering experts. These experts are ready to work on problems concerning equipment and documentation. The SMS related experts are located at the Naval Ship Weapon Systems Engineering Station (NSWSES), Port Hueneme, California.

Problems are reported via DCAP voluntary input forms (fig. 7-2), CONARs, OPNAV 4790/2Ks, feedback reports and the like. In the case of SMS related problems, NSWSES personnel read these reports, extract the problems, and forward the needed information to cognizant departments for action. Engineering personnel at NSWSES and, when required, other activities, analyze the problems and develop solutions.

A problem solution often takes the form of an ORDALT that must be procured and scheduled for installation. In this event, allowance parts lists must also be updated. In other cases, a procedural change is the best solution.

On a monthly or quarterly basis, NSWSES personnel assemble all problem data pertaining to a particular SMS DCAP status report (e.g., AEGIS, TERRIER, TARTAR, Basic Point Defense, NATO SEASPARROW, HARPOON, search radars, or system support/NTDS) and prepare the DCAP status report for publication.

DCAP status reports are mailed to problem originators, and to all similarly equipped units, closing the loop that began when the problem was first reported.

In this way, the DCAP is used to respond to your equipment and documentation problems in a timely manner and to make the problem and

V-0543

UNCLASSIFIED

DCAP VOLUNTARY INPUT FORM
11ND-NSWSES-8810/11A (REV. 5-78)

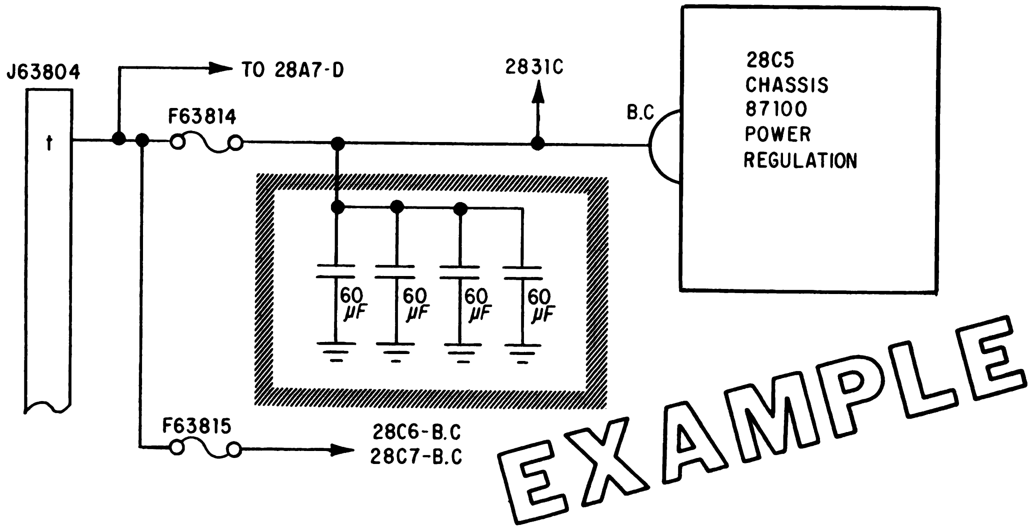
NOTICE: THIS FORM IS NOT MEANT TO REPLACE PMS FEEDBACK (OPNAV 4790/7 SERIES) FOR PURPOSES OUTLINED IN OPNAVINST 4790.4, VOL. I. PROBLEMS REPORTED ON THIS FORM, HOWEVER, WILL RECEIVE THE SAME SCRUTINY AS PMS FEEDBACKS AND ANSWERS WILL BE PROVIDED AS APPROPRIATE.

SHARE AND REPORT YOUR PROBLEMS

DATE 28 AUGUST 1978

PROBLEM: AC RIPPLE ON AN/SPS-48A RADAR RSC RHI SWEEPS

THE AC RIPPLE WAS FIRST ENCOUNTERED IN 1976 AFTER INSTALLATION OF THE RADAR. ALL EFFORTS TO TRACE THE SOURCE OF THE RIPPLE TO A CONCRETE SOURCE FAILED. REPLACEMENT OF THE FILTER CAPACITORS ALSO FAILED TO CORRECT THE PROBLEM AND THE AMPLITUDE OF THE AC RIPPLE PROGRESSIVELY INCREASED, REACHING A POINT WHERE ACCURATE HEIGHT DETERMINATIONS WERE IMPOSSIBLE. THE ITT GILFILLAN TECH REP ATTACHED TO MOTU-5, AL RUSSELL, RECOMMENDED THAT ADDITIONAL FILTER CAPACITORS BE INSTALLED ON THE INPUT VOLTAGE LINE THAT CARRIED THE RIPPLE.



PORTION OF NAVSHIPS 0967-143-2040 TECH MANUAL FIGURE 4-61 PAGE 4-139.

COMMENTS/SOLUTIONS: (Use reverse side if additional space required)

FOUR (4) 60 MICRO FARAD CAPACITORS CONNECTED IN PARALLEL WERE INSTALLED BETWEEN CHASSIS SERIES NUMBER 63800 INPUT +40 VDC UNREG LINE AND CHASSIS GROUND. PHYSICALLY THE CAPACITORS WERE ATTACHED TO THE INPUT +40 VDC LINE AT THE BACK OF FUSE HOLDER F63814 AND GROUNDED TO CHASSIS GROUND BUS, AS SHOWN IN ABOVE DRAWING. THIS SOLUTION, HAS NOT CLEARED UP THE AC RIPPLE COMPLETELY.

MAIL TO: COMMANDING OFFICER
NAVAL SHIP WEAPON SYSTEMS ENGINEERING STATION
ATTN: CODE 0752 (DCAP)
PORT HUENEME, CALIFORNIA 93043

ACTIVITY/HULL NO. USS CONSETELLATION CVG4
RANK/RATE FTM1
WORK CENTER WF06
NAME (Optional) SLOAN, E.E.
REVIEWED BY (if applicable)

UNCLASSIFIED

167.904

Figure 7-2.—Sample DCAP input form.

solution known to all concerned fleet units and shore stations.

OTHER PUBLICATIONS

There are some other NAVSEA publications which are of interest to the FTM. Two such types of publications are the *Naval Ship's Technical Manual* and the *Electronics Installation and Maintenance Book.*

Naval Ship's Technical Manual

The *Naval Ships' Technical Manual* (NSTM) contains guidance and instructions pertaining to classes of installed systems and equipment. The information is in accordance with what is regarded as the satisfactory and safe operation, test, and repair of the equipment. Since the information deals with classes of equipment, it is general information and can provide you with background knowledge additional to the data contained in equipment tech manuals and maintenance requirement cards.

Chapter 400 of the NSTM is on electronic equipment and will be of special interest to you.

Electronics Installation and Maintenance Books (EIMB)

The *Electronics Installation and Maintenance Books* are published by NAVSEA to provide installation and maintenance information for naval electronic equipment. The books are intended to reduce time-consuming research on electronic equipment and circuit theory, and contain a great deal of information of interest to the FTM. The books are divided into several volumes; each volume can be ordered as an individual item.

CLASSIFIED PUBLICATIONS

Many fire control publications are classified. Much of this material is in the confidential category. Generally, the responsibility for handling classified matter involves the receipt of, accounting for, making changes to, and distribution of all such matter.

Safeguarding Classified Matter

The security of the United States in general, and of naval operations in particular, depends in part upon the success attained in the safeguarding of classified information. Security is not a separate burden to be imposed on personnel, but it is a part of the routine duties performed by personnel. The ideal to be sought by all personnel is that they automatically exercise proper caution in the performance of their duties and do not think of security as something separate and apart from their routine work. In this way, security of classified information becomes second nature and poses no additional burden.

You will find some basic information on security in *Basic Military Requirements*, NAVEDTRA 10554 series.

Complete instructions on classified matters are found in OPNAVINST 5510.1, Department of the Navy Information Security Program Regulation. This publication is one with which you should become familiar. Use it as the official source of reference whenever a question of security arises. Also, the above regulation is described in detail in *Security of Classified Information* NAVEDTRA 10975 series.

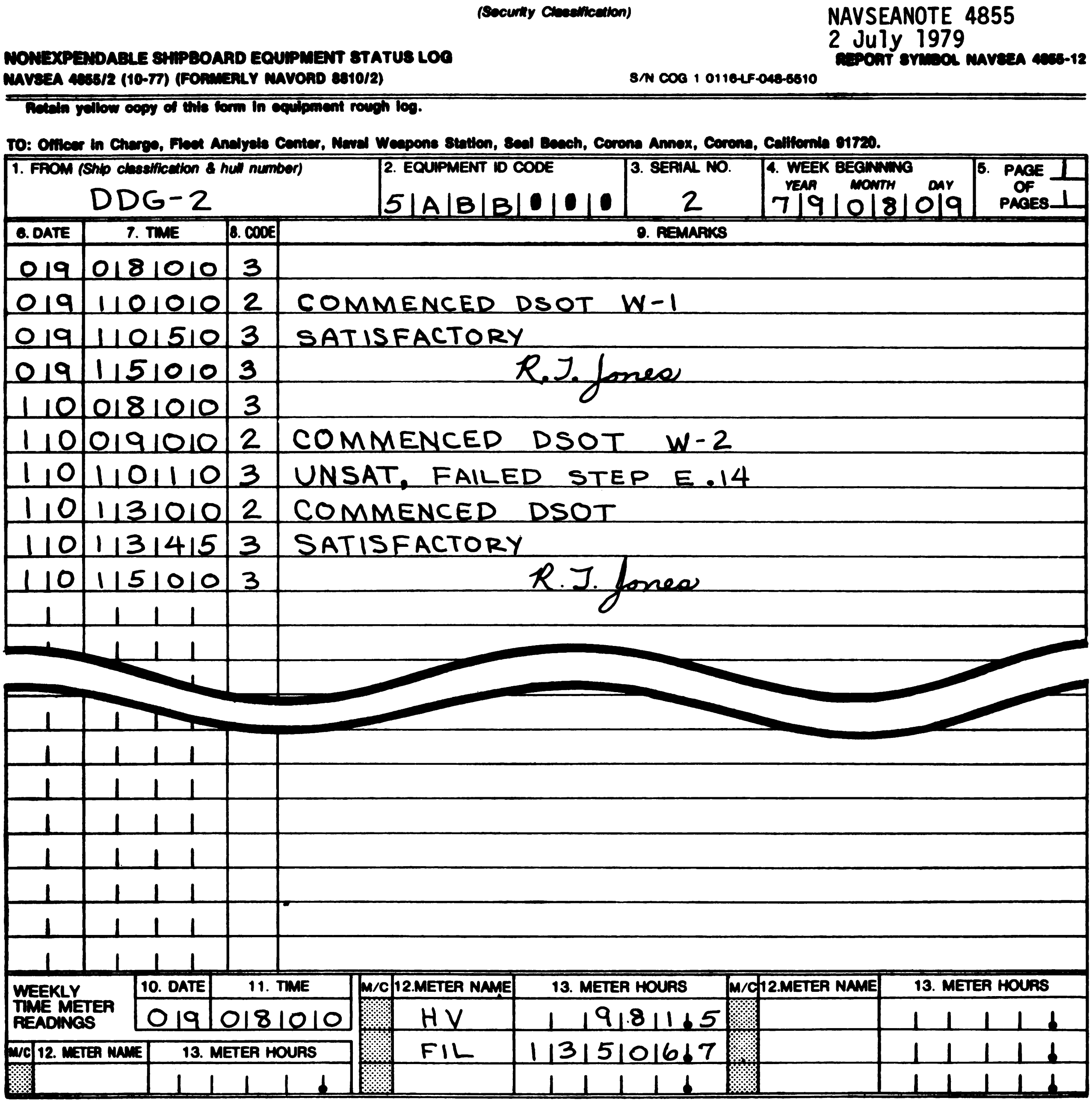
FORMS AND REPORTS

Forms are any printed labels and tags, placards, signs, decals, drawing formats, form letters, or any other duplicated or printed papers which have blank spaces to fill in information to complete their meaning. Forms are used for requisitioning repair parts, recording information, and reporting. Completing a form requires careful reading and checking to make sure the answers are correct. However, it is much simpler and quicker than writing up a narrative report. Also, it makes possible the accurate filing of results, which can be used at many levels.

NONEXPENDABLE EQUIPMENT STATUS LOG

All ships of the operating fleets equipped with surface missile systems shall complete the original and one copy of the Nonexpendable

Equipment Status Log, NAVSEA Form 4855/2 (fig. 7-3) for each piece of equipment applicable. The data on these forms is used to assess the performance of equipment. The assessments serve as the basis for identifying and correcting deficiencies in equipment and system reliability, maintainability, and availability. The originals of each week's logs are to be forwarded within 7 working days after completion to Naval Weapons Station, Seal Beach, Corona,



(Security Classification)

NAVSEANOTE 4855
2 July 1979

NONEXPENDABLE SHIPBOARD EQUIPMENT STATUS LOG
NAVSEA 4855/2 (10-77) (FORMERLY NAVORD 8810/2)
REPORT SYMBOL NAVSEA 4855-12
S/N COG 1 0116-LF-048-5510

Retain yellow copy of this form in equipment rough log.

TO: Officer in Charge, Fleet Analysis Center, Naval Weapons Station, Seal Beach, Corona Annex, Corona, California 91720.

1. FROM *(Ship classification & hull number)*	2. EQUIPMENT ID CODE	3. SERIAL NO.	4. WEEK BEGINNING YEAR MONTH DAY	5. PAGE 1 OF PAGES 1
DDG-2	5ABB000	2	79 08 09	

6. DATE	7. TIME	8. CODE	9. REMARKS
019	081010	3	
019	101010	2	COMMENCED DSOT W-1
019	101510	3	SATISFACTORY
019	151010	3	R. J. Jones
110	081010	3	
110	091010	2	COMMENCED DSOT W-2
110	101110	3	UNSAT, FAILED STEP E.14
110	131010	2	COMMENCED DSOT
110	131415	3	SATISFACTORY
110	151010	3	R. J. Jones

WEEKLY TIME METER READINGS	10. DATE	11. TIME
	019	081010

M/C	12. METER NAME	13. METER HOURS
▨		

M/C	12. METER NAME	13. METER HOURS	M/C	12. METER NAME	13. METER HOURS
▨	HV	981.5	▨		
▨	FIL	13506.7	▨		
▨			▨		

(Security Classification)

94.166

Figure 7-3.—Nonexpendable Equipment Status Log.

California. The log may be filled in by hand. The yellow copy of the 4855/2 is retained by the ship as its equipment rough log; no other log is required. The information recorded on the 4855/2 is not to repeat any maintenance action details that are normally reported on maintenance action form 4790/2K. Use as many 4855/2 forms as necessary to record all information for a 7 day period. Continue entries for the next day on the same sheet if space is available. Make at least one entry at the beginning of every day. This entry should show at least the date, time, and code in the appropriate columns. A final daily entry should show at least the date, time, status code, and signature of the person completing the form. Procedures for completing the 4855/2 are explained in NAVSEAINST 4855. The security classification of the 4855/2 when filled in depends upon the content of the remarks section. If there are no classified remarks, then the form is unclassified and does not need to be marked. Examples of entries which may or may not classify the 4855/2 are:

- Statement that a missile was fired is unclassified.
- Statement of a missile firing, with the results of the firing is Confidential.
- Specific missile frequencies are Secret.
- Routine operations of the equipment, such as DSOTs, tracking operations, loading operations, or system testing, are unclassified.

For the appropriate downgrading statement when the 4855/2 is classified, see *Navy Security Manual* 5510.1 series.

3-M FORMS

Forms used in the maintenance data system (MDS) are described in OPNAVINST 4790.4 and in *Military Requirements for Petty Officer 3 & 2*, NAVEDTRA 10056 series. All the forms described are of importance to you. As an FTM3, you may be required to assist in the preparation of the weekly schedule, OPNAV Form 4790/15.

The use of OPNAV Form 4790/2K is also described in OPNAVINST 4790.4. This form is filled out when you are unable to complete the maintenance work on a certain piece of equipment and it must be deferred until you can get parts and/or assistance from a repair facility. OPNAV Form 4790/2K is also used to report completed maintenance actions on selected equipment. All details on this form must be carefully and accurately filled in. When used for deferred action, it may be several months before you can get repair assistance, and some important information could easily be forgotten in that time. Thus, timely and accurate completion of the form is essential.

CONARs

The commanding officer's narrative report (CONAR) provides a means for an assessment of the entire combat system. Unusual problems dealing with equipment operation, quality control or poor design of parts can be reported. Recommendations concerning manpower and technical publications can also be made.

The CONAR is not meant to replace normal problem reporting methods but only to supplement them.

OTHER REPORTS

You should be aware of the content of the following instructions which deal with specific reports.

NAVSEAINST 8810.3, Reporting requirements for Surface-Launched Missile Firing Tests.

NAVSEAINST 8000.1, Commanding Officers Narrative Report on Surface Weapon Systems

NAVSEAINST 4855.19, Guided Missile Service Reports

To be of value in spotting problems in the missile system, the facts recorded in the reports must be accurate. When you supply data to the person filling out the report, be sure you give correct information.

EQUIPMENT ALTERATIONS

Alterations to ordnance equipment (ORDALTS) must be approved by NAVSEA. An ORDALT instruction furnishes the necessary information to perform the ORDALT, while an ORDALT kit provides the material (hardware) needed for the alteration. A metal ORDALT plate is attached to each major piece of ordnance equipment. The ORDALT plate is normally next to the unit's name plate. The number of a completed ORDALT is stamped on the ORDALT plate as a permanent record. The completion of an ORDALT is recorded in the Nonexpendable Equipment Status Log and reported to the appropriate authority using the OPNAV Form 4790/CK.

NAVSEA ORDALT 00 is an index of all the ORDALTS that have been issued and that are under preparation. The issued ORDALTS are listed by number.

Some equipment of the weapon system is not purely ordnance equipment. As mentioned earlier, alterations to nonordnance equipment are called SHIPALTS.

SHIP ARMAMENT INVENTORY LIST (SAIL)

The Ship Armament Inventory List (SAIL) is a list which indicates a ship's Ordnance Inventory and ORDALT status. It is the primary means used to define hardware configuration and is used to assemble Planned Maintenance System (PMS) packages for ordnance equipment. If the SAIL is not kept current, the odds that the ship will receive an accurate package are low. Each ship has two copies of the SAIL. Prior to a scheduled overhaul, one copy should be annotated with ORDALTS that have been completed since the last printing. This copy is sent to NAVSEA 7 months prior to the scheduled overhaul. The other copy is kept on board. Revised copies of the SAIL are sent to each ship before overhaul. After completion of overhaul, annotate the SAIL to indicate all changes, deletions, additions, and corrections, and forward a copy to NAVSEA.

ORDALT ASSISTANCE

ORDALT kits for SMS equipment are procured and distributed under the control of the Naval Ship Weapon Systems Engineering Station (NSWSES). When feasible, ships are brought to a particular ORDALT configuration during a Repair Availability (RAV) or shipyard overhaul period. This is sometimes referred to as "Block ORDALTING". During these periods, Naval Sea Support Centers (NAVSEACENLANT or PAC) may send ORDALT verification teams aboard your ship to assist you in determining your ship's ORDALT status and requirements. These teams are made up of individuals who are "ORDALT experts", and they come aboard ship to assist you.

SUPPLIES

Although the supply department is responsible for supplies, you need to know how to identify what you want to get, how to write out the request, and how to report on your use of the supplies. The publications containing the stock numbers are maintained in the supply department. Cooperation with supply personnel is essential in performing your own duties.

SUPPLY DUTIES OF THE FTM

Small quantities of supplies are kept in the weapons department and within the divisions of the weapons department. Usually, these are small, frequently used repair parts. As the materials are used, the FTM in charge of the supplies must make replacements. This person has to know how to fill out the request form that is taken to the supply department to request the supplies. These forms are illustrated and explained in OPNAVINST 4790.4 and in *Military Requirements for Petty Officer 3 & 2*, NAVEDTRA 10056 series. These same texts give you information on sources of identification numbers for materials and spare parts. The National Stock Number (NSN) is the most important identification number. All the NSNs are given in the Federal Supply Catalogs; but you may not have to use those to look up a number because the NSN for your equipment is usually found in several other sources. One of these is the Coordinated Shipboard Allowance List (COSAL), described next, and also described and illustrated in the military requirements text.

COSAL

The Coordinated Shipboard Allowance List (COSAL) is the list of all operating equipment and equipage on board a particular ship.

Each major equipment has an Allowance Parts List (APL). An APL contains detailed technical data on the equipment and lists the repair parts needed for that equipment.

Equipage items differ from equipment items in that they are portable and/or high-cost items that are subject to theft. The items (such as, binoculars, stopwatches, typewriters, and test sets) require increased control. The Allowance Equipage List (AEL) describes the range and quantity of equipage items needed to support a ship's mission.

The ordnance/electronics segment of the COSAL has three parts and uses the same format as that shown in your military requirements text.

Part I contains a ship-tailored list of all current APL and AEL numbers. It also contains an index of equipment and equipage with their assigned APL/AEL numbers.

Part II is made up of APLs and AELs. The quantity of each item and the National Stock Number is given. Anything listed in Part II should be available aboard ship. You can usually find a copy of your equipment's APL in the department office or in your work space.

Part III of the COSAL is the final authorized on-board allowance quantity for a repair part. This is of greatest use to the storekeeper. Items that are common to more than one department are totaled in this section. For example, a certain type of switch may be used in various applications on the ship. Part III of the COSAL tells how many are to be on board and how many are allotted to each department. Also included is a part-number-to-stock-number cross reference which may be helpful in finding the NSN of an item.

SOURCES OF IDENTIFICATION

In order to request a repair part for your equipment, you must be able to identify that part in terms of the supply system. The publications most often used to identify ordnance/electronic material are:

- NAVSEA OPs and technical manuals which contain parts lists (fig. 7-4) and, in some cases, a related illustrated parts breakdown (IPB) (fig. 7-5).

- Manufacturers' technical manuals.

- The ordnance and electronics parts of the Federal Supply Catalog.

- The Coordinated Shipboard Allowance List (COSAL), which was already discussed.

The first two publications usually provide only a manufacturer's part number, a drawing number or design control number, or the like. The last two provide an NSN. In any case, the NSN is needed for the requisition form. Another source of identification is the information on name plates. This may include the manufacturer's name, item make or model number, size, voltage, and similar information.

MANDATORY TURN-INS AND REPAIRABLES

You will no doubt encounter the terms "mandatory turn-ins" and "repairables" in the process of obtaining replacement parts from supply. It will be helpful if you understand the purpose of the program and your part in it.

BREAKDOWN AND INDEX NO.	REFERENCE DESIGNATION	PART NUMBER	INDENT	DESCRIPTION	MFR's NO.	QTY PER ASSY
7-18-		2805328G1	1	SYNCHRO ASSY, Elevation Data		Ref
-1	1A2MP55	102696P42	2	CLAMP		3
				(Attaching Parts)		
		MS51957-63	2	SCREW, Pan Hd		3
		MS35338-138	2	WASHER, Lock		3
				---*---		
-2	1A2B1	M20708/45-001	2	SYNCHRO, Transmitter Control Type 23CX4d		1
				(Attaching Parts)		
		MS17187-3	2	NUT, Hex		1
		MS17186-8	2	WASHER, Drive		1
				---*---		
-3	1A2MP57	1596821P1	2	GEAR, Spur		1
-4	1A2MP58	MS17183-2	2	CLAMP ASSY		3
-5	1A2B3	M20708/19-001	2	SYNCHRO, Transmitter Receiver Type 15TRX4a		1
				(Attaching Parts)		
		MS17187-2	2	NUT, Hex		1
		MS17186-6	2	WASHER, Drive		1
				---*---		
-6	1A2MP56	1596820P1	2	GEAR, Spur		1
-7		1473251P1	2	PLATE, Machined Casting		1

167.905

Figure 7-4.—Sample parts list.

When any of your equipment fails, your main concern is to locate the trouble, correct it, and get the equipment "back on the line." In most cases, this involves tracing the trouble to a defective part, obtaining the replacement part from the supply storeroom and installing it, and throwing away the defective part. When the defective part is expensive and repairable, the repairables program is used.

A large number of parts can be cheaply repaired when they fail. This results in savings of dollars and time, since it is quicker and cheaper to repair an item than to contract for and buy a new one, provided that the old item is promptly returned in repairable condition. For the program to work as intended, you and others have certain responsibilities. At the time your request for a mandatory turn-in item is presented to supply personnel, they must inform you that the item is to be returned. At this point your responsibilities begin. You must:

- Remove the defective part without damaging it.

- Provide adequate protection to the part so that it will not be further damaged before it is turned in to supply. The most effective way, for all concerned, is to place the defective part in the same container in which you received the replacement part.

- Resist the temptation to cannibalize the part for components which you might possibly use sometime in the future.

- Return the defective part to supply as soon as practicable.

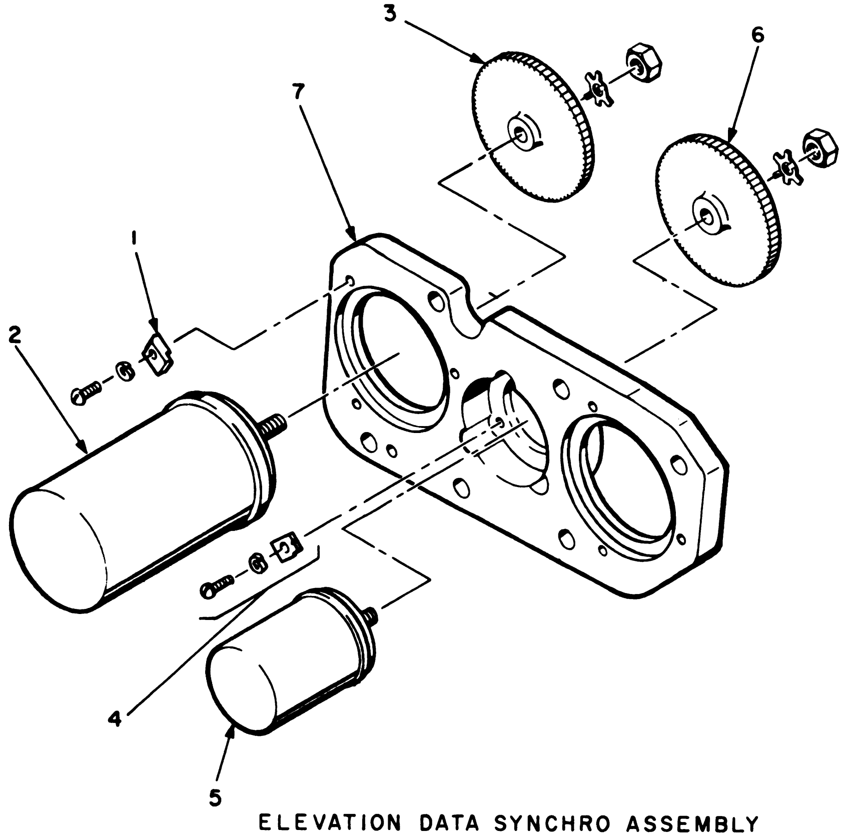


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Figure 7-5.—Sample illustrated parts breakdown.

When the required part is not in the storeroom, supply must then take proper action to obtain it. The failed part must still be returned and should be turned in prior to receiving the replacement part. This way the failed part can enter the repair cycle and be available for reissue that much sooner. The only exception should be when the failed part permits limited or reduced operation of a piece of equipment until the replacement is received.

Now that you know the procedures for obtaining repair parts, let's go on to the next chapter. There you will learn, among other things, how to make use of these parts in maintaining your "gear."

CHAPTER 8

TROUBLE ISOLATION AND GENERAL MAINTENANCE

The usefulness of your equipment depends largely on the care you give it. A misaligned director, for example, can reduce the accuracy of a perfectly aligned missile system. A malfunctioning radar increases the difficulty of detecting and tracking targets. An inoperative fire control computer makes it impossible to effectively engage a target. In each case, action of some sort is required to cause the equipment to operate properly.

The work you perform on equipment falls into two broad groups. First, there are actions you take to reduce failure and prolong the useful life of your equipment. Second, there are actions you take when a part has failed and the equipment is out of service. Therefore, we can think of the whole business of general maintenance as being of a PREVENTIVE nature or of a CORRECTIVE nature.

In maintenance work of any type, you must use knowledge and skills of two basic types. First, you must have SPECIFIC information which applies only to the particular system or part of it which you may be called upon to repair or keep in good condition. Second, you must possess and use certain GENERAL skills and knowledge which apply to many kinds of equipment and to many types of work assignments.

The specific information required consists of the special procedures and detailed, step-by-step directions for maintenance. These are approved by the proper authority and recommended for a particular system or piece of equipment. These procedures and instructions are found on Maintenance Requirement Cards (MRCs) and in the system and equipment ordnance pamphlets (OPs) and technical manuals (TMs) of the missile system to which you are assigned.

Due to the complexity of surface missile systems (SMS) equipment and the magnitude of SMS maintenance requirements, it would be impractical for this chapter to detail step-by-step procedures for specific maintenance actions. However, the mechanics of SMS maintenance procedures and trouble isolation are discussed. Many of the troubleshooting aids that have been developed over the years are reviewed so that you can take part in a useful maintenance program.

General maintenance techniques are also discussed. Emphasis is placed on those skills and procedures which can be applied in all shipboard maintenance programs. The general maintenance skills and procedures are based on knowledge which is not contained in system or equipment OPs/TMs. The knowledge must be acquired on the job and from rate training manuals.

The last part of this chapter is devoted to maintenance safety precautions. Again, the discussion is of a general nature. Specific safety precautions are listed on every maintenance requirement card (MRC) where there is a chance of hazardous conditions developing. Safety summaries that cover general safety precautions are included in volume 1 of OPs and TMs.

PREVENTIVE MAINTENANCE

Maintenance that you perform to make future troubles or problems less likely is usually referred to as preventive maintenance. This form of maintenance consists mainly of cleaning, lubrication, and visual inspection of the equipment prior to and during its operation. Scheduled alignments and adjustments are also included in this category. Preventive maintenance procedures are provided by and scheduled according to the Planned Maintenance System.

CORRECTIVE MAINTENANCE

When a defective part or improper operation is indicated, you will need to analyze the equipment, find the defective part or parts, and make the proper replacement or repair. In general, your analysis will be most effective if you follow a careful and logical step-by-step trouble shooting procedure. This will be discussed later in this chapter.

BASIC MAINTENANCE PROGRAM

Preventive maintenance, then, consists of the care, upkeep, and minor repairs and adjustments performed by you, the technician, to ensure the best condition of your equipment and to reduce the chance of sudden equipment failure or malfunction. Preventive maintenance aboard SMS ships is accomplished by means of scheduled system and equipment performance tests, scheduled servicing procedures, and careful observation of system/equipment performance during periods of operation. These schedules are posted weekly in each work center and act as the guide for maintenance actions.

When preventive maintenance or performance checks reveal that a casualty or malfunction exists in a system or a piece of equipment, some form of corrective maintenance is needed. Some action is required that will restore the system or equipment to its designed use. This includes the repair of damage resulting from wear, accident, or other cause.

THE PLANNED MAINTENANCE SYSTEM

Planned maintenance is based on the principle that readiness can be determined through testing, and thoroughness can be assured by proper scheduling. This maintenance program, known as the Planned Maintenance System (PMS), is incorporated in your system and equipment OPs.

SYSTEM MAINTENANCE

Some maintenance tests are conducted on a system level, as mentioned in chapter 2. If a fault appears, PMS troubleshooting material provides a means for testing which leads to positive and rapid identification of the exact equipment causing the trouble.

System maintenance uses quick tests to locate faults in a system; it also lists the methods and procedures needed to repair these faults. The Planned Maintenance System is designed so that experienced technicians can share the workload with less experienced personnel. Along with this, it has established that important tasks be grouped as scheduled maintenance events.

To see the value of system level testing, let us suppose that a misalignment exists between two sets of equipment, such as a search radar and a fire control radar. Individual equipment tests would probably indicate that both radars were operating properly. In actual operation, however, the fire control radar would be unable to acquire the targets disclosed by the search radar due to the misalignment. System level testing, however, would consider one equipment's performance with respect to another's and provide you with the data that points out the alignment problem.

Those individual circuits and system modes which cannot be readily checked in the Daily System Operability Test (DSOT) are judged by conducting extra system tests and equipment tests. These, plus the standard servicing procedures, are also listed as scheduled maintenance events. The Planned Maintenance System requires the scheduling of these test and maintenance tasks into the ship's operating schedule according to a fixed management plan. Requirements for those recurring tests have been set up to provide the minimum testing necessary to ensure material readiness. The PMS program has done away with overtesting, has to a great extent relieved the excess workload imposed on technical personnel, and has reduced needless wear on equipment. The intervals at which tests and other maintenance tasks are performed have been fixed in accordance with the CNO's

Planned Maintenance System. These schedules are an integral part of the Planned Maintenance System.

The Maintenance events are arranged by the ship's weapons officer to fit the ship's operating schedule. This allows the appropriate maintenance procedures to be continued whether the ship is in port or at sea. The primary reason for conducting the tests is to determine the operability of the weapons system. If a response should indicate a fault which prevents the system from operating at the required degree of combat readiness, PMS troubleshooting references are consulted. These references are pointed out by keys in the test procedures, and not only will they lead to the exact location of trouble in the shortest possible time but they will also specify the corrective measures.

EQUIPMENT MAINTENANCE

Even though you, as an FTM, will be an active participant in system maintenance procedures, your participation will normally be limited to the equipment area to which you are assigned. Therefore, it is mandatory that you become familiar with the details of equipment maintenance procedures. There is a separate Ordnance Pamphlet or technical manual (OP/TM) for each major piece of equipment. This OP/TM contains a description of the equipment, its operating procedures, the maintenance turn-on procedures, and the equipment troubleshooting material. These equipment pubs have been specifically created to quickly isolate faults within the equipment. Direct referral to the troubleshooting section is from system fault directories and diagrams, and from the equipment turn-on procedures and the troubleshooting index.

In chapter 4 of this manual, we mentioned that system tests were printed on MRCs. This also applies to equipment test procedures. The format of the test is the same, but troubleshooting references listed are equipment-related vice system-related OPs/TMs. Next, we will discuss the most common types of equipment maintenance documents.

TROUBLESHOOTING AIDS

Chapter 7 of this manual explained the purpose of OPs and TMs. Now, let us take a closer look at the contents of these pubs and how you can use them. Remember, these are your prime troubleshooting aids.

As mentioned earlier, the maintenance turn-on procedure and the troubleshooting index can be used to guide you to the correct area in the maintenance documents. The maintenance documents include but are not limited to signal flow diagrams, relay and lamp indexes, relay and lamp ladder diagrams, power distribution diagrams, and schematic diagrams.

Maintenance Turn-On

The maintenance turn-on procedure (fig. 8-1) is a troubleshooting document that lists the step-by-step procedure used to energize the equipment. It lists the correct indication for each step and the troubleshooting references for out-of-tolerance observations. This procedure is performed prior to any other maintenance test and whenever the normal turn-on procedure indicates a problem. The maintenance turn-on procedure parallels the normal operation turn-on steps to ensure that faults occurring during normal turn-on are covered.

Troubleshooting Index

The troubleshooting index contains a list of the equipment's outputs (fig. 8-2). For each function, the associated columns indicate the fire control symbol (if one applies), the destination, and the related mode of operation. The index also contains references to direct the technician to the related signal flow, schematic, or relay and lamp ladder diagram.

Signal Flow Diagrams

Signal flow diagrams (fig. 8-3) are a combination of schematic and block diagram types of drawings. They collectively show the functional development of equipment outputs in

Step	Procedure		Observation	Reference
1	Check that all primary power is available to the radar.		SHIPS POWER lamp on radar console shelf is lighted.	Fig. 5-25
2	Insure Coolant group is activated in accordance with instructions.			NAVSEA 948-LP-118-1010
3	Place the following front panel switches at the positions indicated			
	Switch	Position		
	TRANSMITTER CONTROL 11/12A4S1	REMOTE	OFF section of OFF REMOTE CONTROL pushbutton indicator on radar console is lighted	Fig. 5-22
	STATION SELECTOR 9/10A1S2	OPERATORS CONSOLE	OFF section of CWI TRANSMITTER OFF-REMOTE CONTROL pushbutton indicator on radar console is lighted.	See OP4350
4	Depress TRACK TRANSMITTER-LOW VOLT STANDBY pushbutton indicator 1/2A2S15.		TRACK TRANSMITTER-LOW VOLT STANDBY pushbutton indicator on radar console lights yellow.	Fig. 5-22

Figure 8-1.—Part of a maintenance turn-on procedure.

Function Title	To	Mode	Signal Flow Diagram Fig. No.	Schematic Fig. No.	Relay Ladder Fig. No.
Accept Designated Range	Computer complex and NTDS	Track and Passive Track		6-2 (1/2)	5-24
Air Track	Computer complex	Track	5-16	6-2 (1/2)	5-24
Bearing Correction q(By)	Computer complex	Surface Track	5-16	6-2 (1/2)	5-24
Break Track	Computer complex	Track	5-16	6-2 (1/2)	5-24
Burnthrough Power	Track Xmtr	Track-Freq Agility	5-2	6-2 (1/2)	5-24

Figure 8-2.—Part of a troubleshooting index.

relation to the rest of the weapon system. This includes the outputs (scope displays) to the operator and the outputs (rf transmissions) to the selected target. These drawings are intended for use as training aids as well as troubleshooting documents. The drawings show all test points with their ideal values and tolerances. They also point out the adjustable components and provide useful notes (fig. 8-3).

Some signal flow diagrams are drawn for a specified operating condition, for example, the track mode. These conditions are outlined under

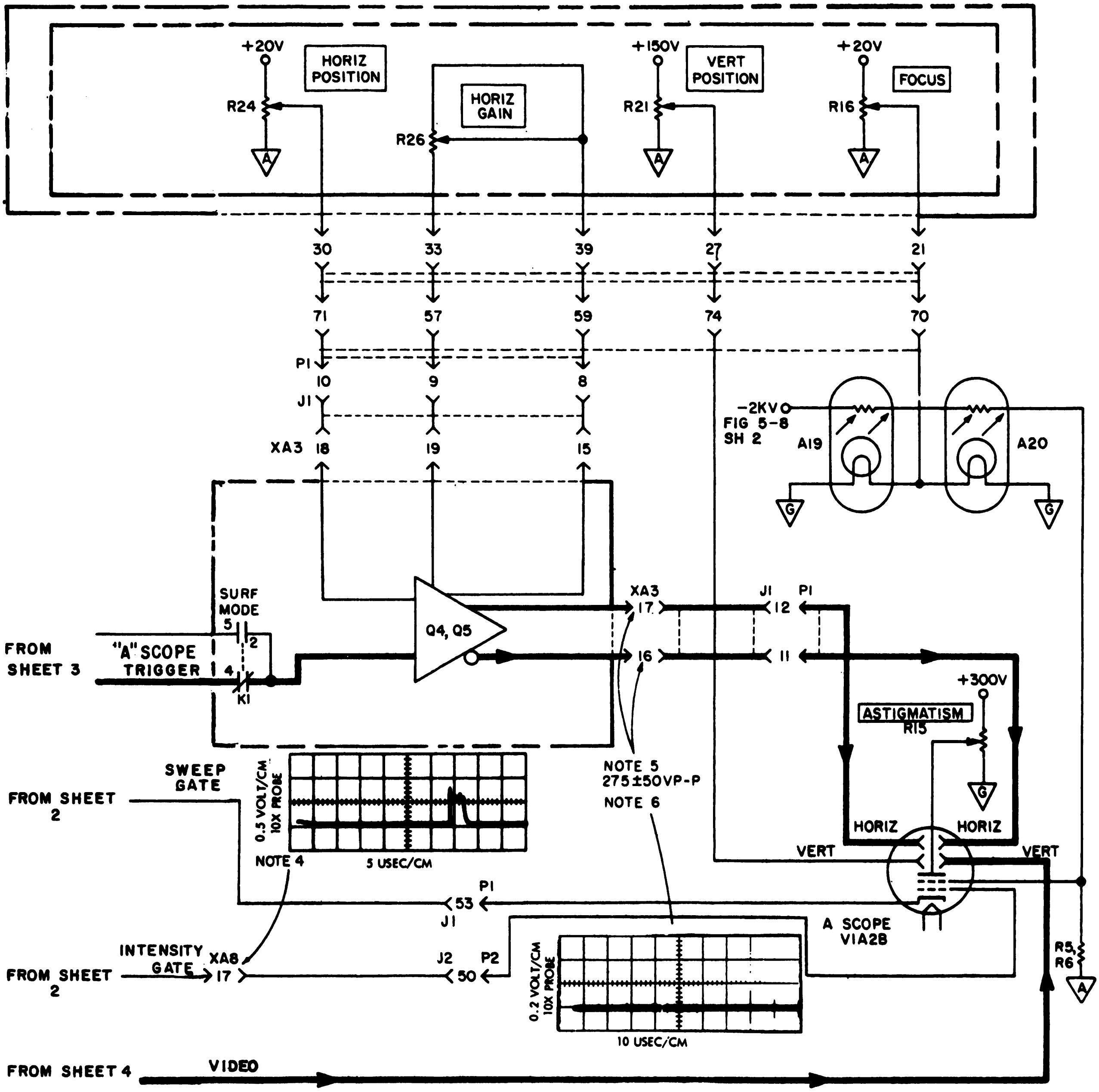

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Figure 8-3.—Part of a signal flow diagram.

the heading GENERAL NOTES, on page 1 of each drawing. All scope and meter indications would then conform to these dynamic conditions. The signal flow diagrams are limited in their use as troubleshooting aids since they show normal operation parameters and do not show parameters which would be obtained under troubleshooting or test conditions.

Signal flow diagrams are titled with a selected output function (selected because it covers the greatest amount of equipment circuitry). Where the selected output function has a multimode characteristic, it is so designated in the drawing title. The main signal path, outlined by heavy lines, is shown in the primary equipment mode of use.

The path of main signal flow is, with minor exceptions (such as feedback loops), from left to right on each drawing sheet with the primary output appearing at the right-hand side of sheet 1. (In this case, the scope presentation is the output.)

All circuits which affect the signal being traced and which are not shown on the signal flow diagram are referenced to drawings on which they are illustrated in detail. This cross-referencing includes:

- References to power distribution diagrams.

- References to other signal flow diagrams. Circuitry which is common to more than one output function is covered on one signal flow drawing and referenced on all affected signal flow diagrams.

- Specific references to the relay ladder diagrams for operation of relays which are not illustrated on the signal flow diagram.

Signal flow diagrams are especially useful in tracing signal continuity between functional circuits. The complete signal path is traced on one diagram through below-deck and above-deck cabling, sliprings, cabinet backboards, connectors, and individual units.

Relay and Lamp Indexes

The relay and lamp indexes (fig. 8-4) list all of the lamps and relays shown on the troubleshooting diagrams. The indexes list, in unit designation sequence, all relay coils and related switches and indicator lamps. They cross-index by figure, sheet, and zone the location of the relay coil and indicator lamp energizing paths.

Relay and Lamp Ladder Diagrams

Relay and lamp ladder diagrams (fig. 8-5) show the energizing paths for relays and indicator lamps that are not covered by signal flow diagrams. They are usually used along with relay and lamp indexes.

The relay and lamp ladder diagram traces the energizing path for the relay coil or indicator lamp from a common interface point appearing on both a power distribution diagram and the ladder diagram. It traces through the equipment, to the respective relay coil or indicator lamp, and to a common return power interface. The relay and lamp ladder diagrams show cabling, terminal connections, relay contacts, switches, and lamps in the energizing path.

The relay and lamp ladder diagram is intended for use as a troubleshooting support document for the signal flow diagrams and the maintenance turn-on procedure. It is also to be

Relay or Lamp	Function	Coil Supply (Vdc)	Fig.	Sheet	Zone
17A1A5K1	CWI Modulation ON	50	5-23	9	B5
K2	CWI Modulation ON	50	5-23	9	B6
XDS41	Test Alarm	50	5-23	14	B1
	No Go	50	5-23	14	B1
XDS45	Test Alarm	50	5-23	14	B3
	No Go	50	5-23	14	B3
XDS49	Control Alarm	50	5-23	12	B6
	Test Alarm	50	5-23	12	B5

Figure 8-4.—Part of a relay and lamp index.

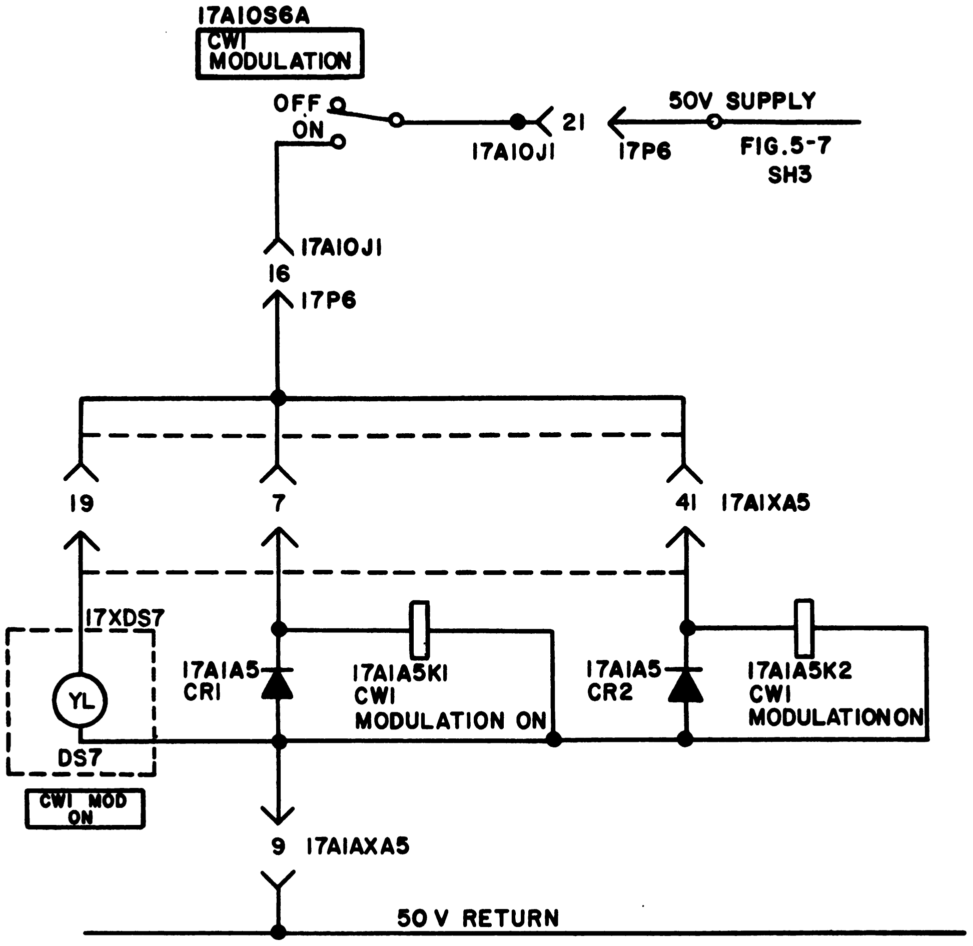

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Figure 8-5.—Part of a relay and lamp ladder diagram.

used as the prime troubleshooting document for equipment switching problems.

Power Distribution Diagrams

Power distribution diagrams (fig. 8-6) are troubleshooting support diagrams for the signal flow diagrams, the relay and lamp ladder diagrams, and the maintenance turn-on procedure. Specific references to the power distribution diagrams are made in the related troubleshooting aids for the purposes of (1) completing the circuitry related to specific equipment outputs and (2) trouble isolation of equipment power failures.

Power distribution diagrams show the routing of a.c. and d.c. power used as power sources and reference voltages. All of the diagrams are indexed for the technician's convenience in the table of contents. Each diagram shows the distribution of power from the power source to the cabinets and chassis of the equipment. Each diagram also shows the terminal boards and cable connections between the boards.

Schematic Diagrams

A schematic diagram shows how the parts of a circuit are connected for the operation of the

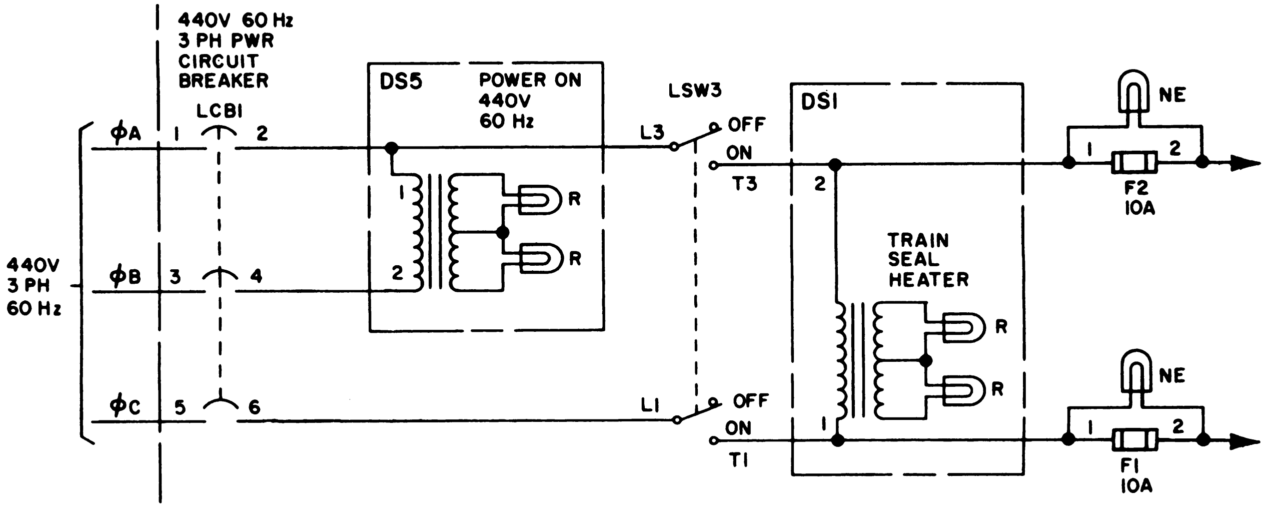

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Figure 8-6.—Part of a power distribution diagram.

equipment. It does not tell how the parts look or how they are made. Each component is pictured by a symbol. A set of schematics enables a technician to trace the passage of energy throughout the entire equipment. The details of each circuit are drawn.

The PMS trouble isolation procedures refer you to the suitable schematic diagram when there is need for detailed circuit information.

TROUBLESHOOTING

Much of your time as a Fire Control Technician is spent troubleshooting the equipment to which you are assigned. Your job may be to maintain or help maintain a number of units within the fire control system. Some of them are quite complex and might seem, at a glance, beyond your ability to maintain. However, the most complex job usually becomes much simpler if it is first broken into successive steps. Any maintenance job should be performed in the following order:

1. Analyze the symptom.
2. Detect and isolate the trouble.
3. Correct the trouble and test the work.

BASIC TESTS

In troubleshooting, as in most other things, there is no substitute for common sense. In fact, the application of a little common sense, in many cases, will greatly simplify your problems. Consider the following situations.

If there is no input power present to the equipment, it may be assumed (temporarily) that the equipment is not at fault. Check all applicable switch positions, circuit breakers, fuses, and the like, then check for power at the bus which feeds the equipment. Check the tightness and physical condition of cable connections. Using the schematic diagrams in the OPs, check at successive connection points for continuity, short circuits, or grounds.

If a circuit breaker is tripped or if a fuse is blown, a circuit fault is indicated. Power to the circuit containing the "open" should be turned off, and should not be reapplied until the fault is located and corrected. The most common causes of tripped or blown circuit protectors are short circuits, faulty grounds, or overload conditions. However, circuit protectors sometimes fail due simply to age or to transient conditions. If, after a thorough check, no apparent reason for the failure can be found, the breaker may be reset or the fuse replaced with another of the proper size and type, and the power reapplied. If the protector fails again, a fault is definitely indicated.

A common cause of equipment malfunction is a loss of power or signal to a circuit. Faults which may interrupt current through (open) a circuit include broken wiring, loose or faulty terminal or plug connections, and faulty relays or switches. With the equipment turned off, continuity checks can usually locate this type of fault.

After a defective unit has been identified, it is also wise to try to find the reason for the failure of the unit. It is possible that the new unit may also be damaged if the original cause is not corrected.

After replacement of the faulty unit an operational check is performed. During the operational check, any readjustments or calibrations should be made as required.

SIGNAL TRACING

Signal tracing is a very effective method for finding faulty stages in many types of electronic equipment. It is especially useful when servicing equipment which does not contain built-in meters. The signals are checked at various points in the equipment, unit, or circuit using test instruments such as vacuum tube voltmeters, oscilloscopes, or any suitable high impedance instrument, for signal tracing. The test instrument should have a high impedance so that it will not change the operation of the circuit to which it is applied.

When using the signal tracing technique to measure a.c. signals, be sure that the test instruments are adequately isolated from any d.c. potentials present in the circuit. Some test instruments are equipped with special a.c. probes which include a capacitor in series with the input for this purpose. Before using any piece of test equipment, you must be familiar with the features and proper use of the test equipment, as well as with the equipment under test.

The gain or loss of amplifiers can be measured using signal tracing methods. Sources of distortion and hum, noise, oscillation, or any other abnormal effect can also be isolated.

TEST PROBE SUBSTITUTION

Using a test probe with test equipment other than that for which it was designed may result in a sizable error. Any differences in the internal resistance of the probe and the input circuitry of the test equipment bring about a need for calibration. For example, the internal resistance of a 10:1 probe is, in most cases, nine times higher than the input circuitry of the test equipment. It should be noted that 1:1, 50:1, and 100:1 probes are available, as well as 10:1 probes.

Test probes which are not recommended for specific test equipment should not be used, because they may not have enough capacitive adjustment to preserve the waveshape of the observed signal. A sound rule is to use a test probe only with the test equipment for which it was designed.

REPAIR

In spite of the greatly increased reliability of solid state circuitry, failures still occur. Special attention must be paid during the repair and replacement of these components. With the discrete miniature component (transistor, semiconductor, resistor, etc.), you can test individual circuit elements and determine the cause of failure, then repairs can be made by replacing the faulty component. With the integrated circuit (IC), replacement of an individual part is not always possible. The repair then becomes a matter of isolation and replacement of the defective "chip", printed circuit (PC) board, or module.

Modules

Solid state assemblies are more rugged than conventional circuits. They are, however, susceptible to damage from improper handling, power surges, and overheating. Increased care is necessary in the performance of maintenance and servicing. The small size and close spacing of parts within the assembly require more care and smaller tools. Special devices and maintenance aids are needed to provide the precision required for such close work.

Component damage during maintenance is usually the result of excessive heat during repair, reversed polarity of ohmmeters while checking for continuity, application of excessive voltages during tests, rough handling, or use of the wrong tools or materials.

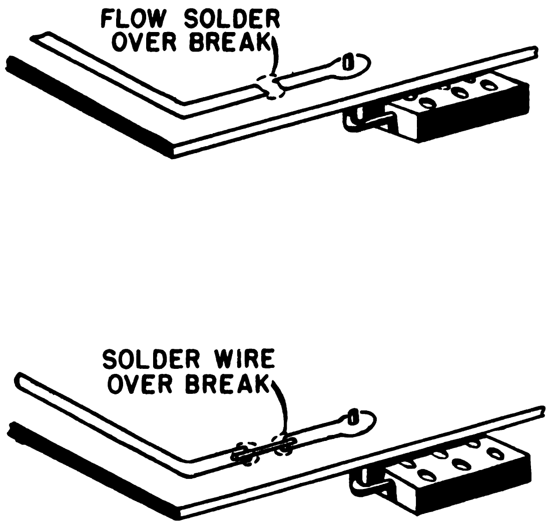
Loosening connections, inserting or removing transistors, and changing modular units should be done with the circuit deenergized. Otherwise a power surge could occur, which might damage the component. It is important to remove any capacitive charge from test equipment before connecting it to a modular unit. A grounding clip should be connected to the modular chassis before applying test probes. When disconnecting, the grounding clip should be removed last.

Leads to transistors, capacitors and the like are easily damaged in handling, stowage, and shipping. Proper precautions should be used at all times. It should be emphasized that these components and circuits can be repaired, if adequate care and proper techniques are used.

Printed Circuits

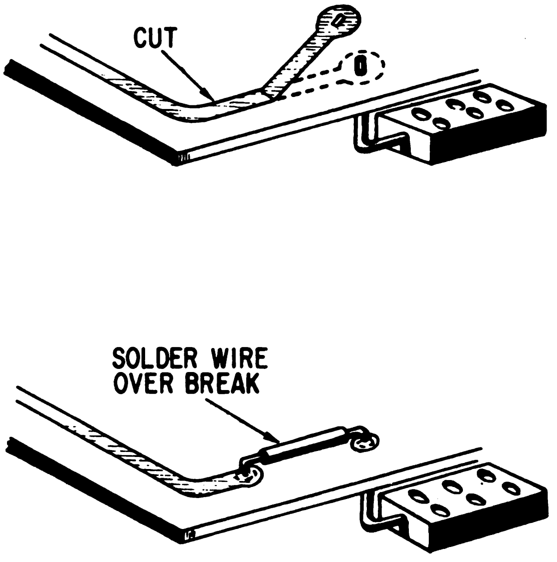
The printed circuit presents certain difficulties in soldering techniques that are not common to the older wired circuits. Should a printed circuit foil break, it is easily repaired by placing a short length of bare wire across the break and soldering both ends to the print. If the break is small, simply flow solder across the break. Refer to figure 8-7. In both cases, be careful not to apply too much heat, and do not allow solder to flow to other printed areas. In cases of separation of the foil from the board, repair can be made using a piece of wire (fig. 8-8).

Removal of a component from a printed circuit board without damage to the board or other components requires precision and skill. A pencil iron and special tips are preferred and should be used whenever possible. Components



228.28

Figure 8-7.—Repairing breaks in foil.



222.257

Figure 8-8.—Repairing raised portion of foil.

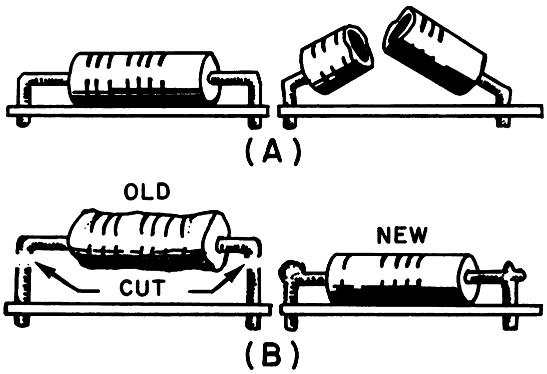
such as resistors and small capacitors are most easily removed if first cut to free their leads (fig. 8-9A). Also, less heat is required. When access to the foil side of the board is not possible, cut the leads of the component. The new part can then be soldered to the remaining portion of the old leads (fig. 8-9B).

PART REPLACEMENT

Don't believe all the stories you might hear about bubble gum and baling wire. Should it become necessary to replace a part with a substitute, you must make sure that you use a proper replacement. With resistors, for instance, several characteristics must be considered: for example, ohmic value, wattage rating, tolerance, physical size, and type of construction. Capacitors require consideration of physical size, capacity, tolerance, temperature coefficient, and voltage rating. Plugs and connectors almost always have to be exactly as prescribed, since it is difficult to find items of this type that are interchangeable.

The *Navy Electricity and Electronics Training Series* (NEETS) contains information on color codes for resistors and capacitors in modules 1 and 2, respectively. Refer to these for standard codes, design details, physical shapes, methods of reading, and tolerances.

Repair techniques are also described in depth in the NEETS series, so are not discussed here.



228.31
Figure 8-9.—Replacement of a resistor on a printed circuit.

CHECKING AFTER REPAIR

No repair job is complete until the repaired component or unit is reinstalled and actually operating properly. After the faulty component has been replaced and the unit reassembled, dust and shield covers must be replaced. Sometimes a shield or plate that has been installed touches a bare wire or other contact and causes a new problem (if it was not the original problem).

After the component or unit is reinstalled in the equipment and properly secured in place, it must be given a final operational test. The most important test is a dynamic check under normal operating conditions. When the component or unit performs properly in the equipment and is securely mounted, the casualty has been repaired. The completed maintenance can then be documented in accordance with the Maintenance Data System.

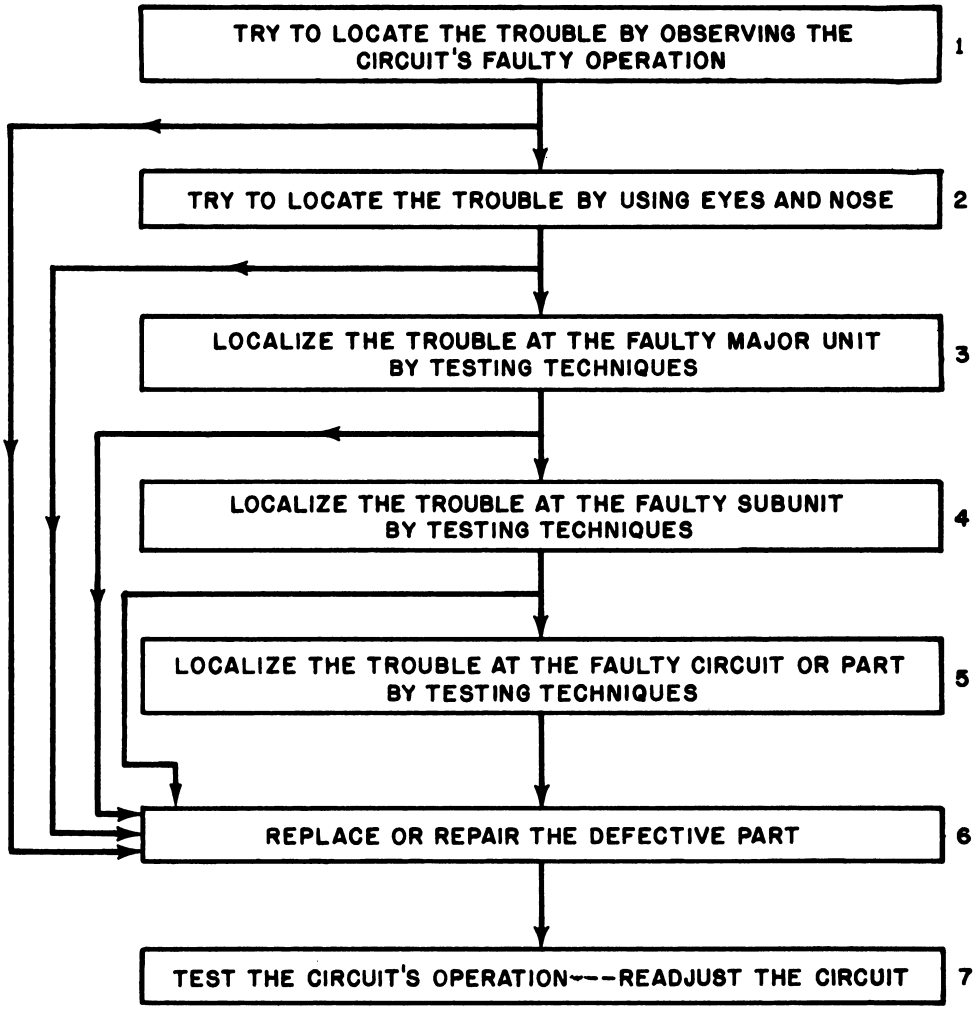
At times a new part will have a different value than the replaced part (as in the case of resistors, capacitors, and semiconductors). Even though the equipment operates properly, it may need an adjustment or two to bring it up to peak performance.

The troubleshooting steps that we have been discussing are summarized in figure 8-10, which shows in chart form a general troubleshooting procedure. The directions given in blocks 1 through 5 are steps to be used in locating the trouble, and the directions given in blocks 6 and 7 are steps in repairing the equipment. (Steps 2, 3, 4 and/or 5 may sometimes be eliminated, but steps 6 and 7 will always be followed.)

MAINTENANCE REQUIREMENT CARDS (MRCs)

You are already familiar with the use of maintenance requirement cards in system and equipment tests. The MRCs are also provided to assist you with many of your corrective maintenance tasks.

The format for each of these cards is the same (fig. 8-11). However, instead of the periodicity code (M-1, D-2, W-3, etc.), these MRCs are assigned a number preceded by the


TRY TO LOCATE THE TROUBLE BY OBSERVING THE CIRCUIT'S FAULTY OPERATION
1
TRY TO LOCATE THE TROUBLE BY USING EYES AND NOSE
2
LOCALIZE THE TROUBLE AT THE FAULTY MAJOR UNIT BY TESTING TECHNIQUES
3
LOCALIZE THE TROUBLE AT THE FAULTY SUBUNIT BY TESTING TECHNIQUES
4
LOCALIZE THE TROUBLE AT THE FAULTY CIRCUIT OR PART BY TESTING TECHNIQUES
5
REPLACE OR REPAIR THE DEFECTIVE PART
6
TEST THE CIRCUIT'S OPERATION---READJUST THE CIRCUIT
7

167.801

Figure 8-10.—Troubleshooting procedure.

letter-U (unscheduled) and are listed on a separate Maintenance Index Page (MIP).

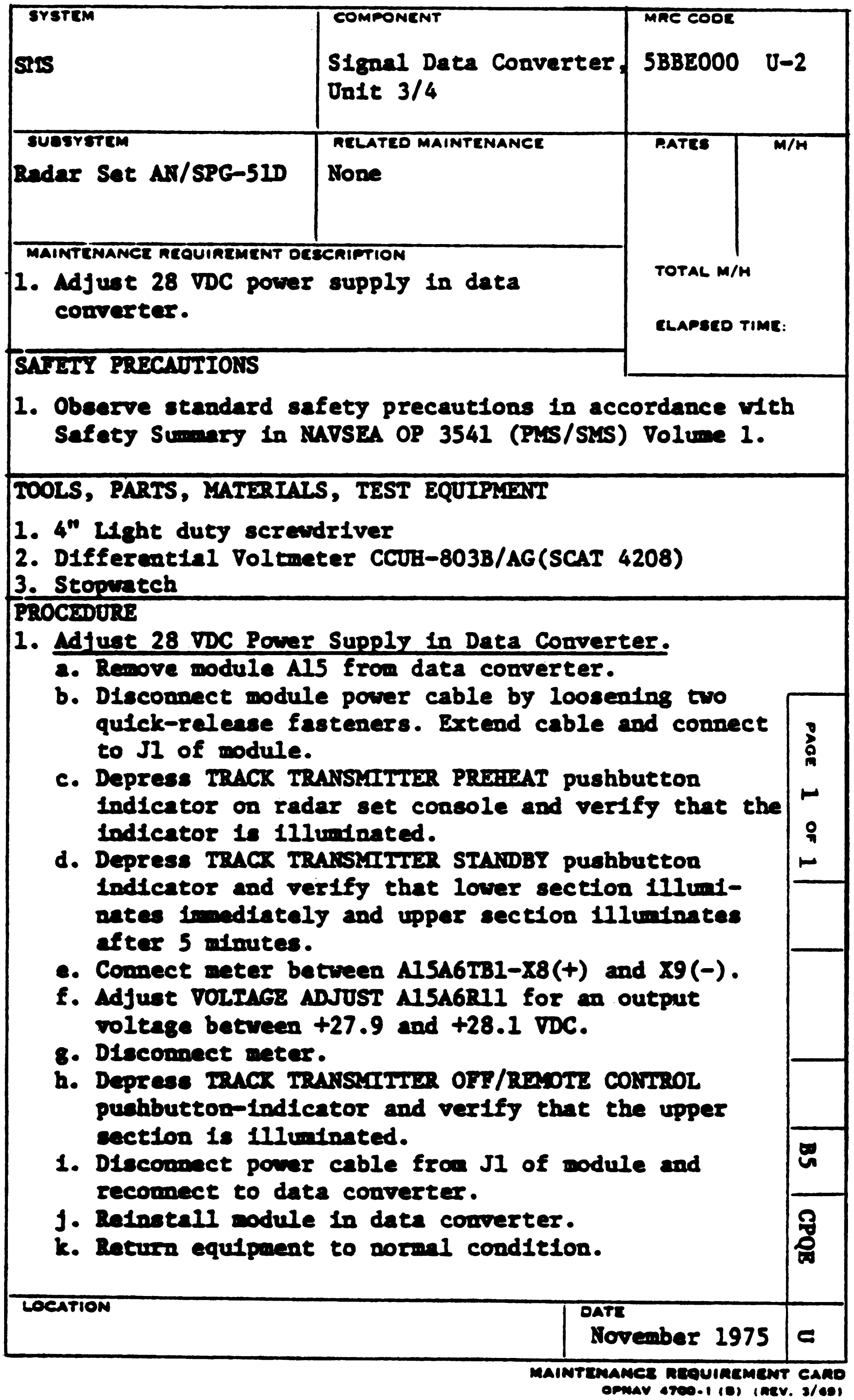
The tasks covered in these MRCs fall into two groups. One group consists of repair/replacement procedures. These MRCs refer to those components which are most easily repaired and most often replaced. The procedures help you to perform the maintenance actions safely and in an orderly manner so you do not end up with "extra parts" when you think you have finished.

The other group is made up of alignment/adjustment procedures. These MRCs are intended for use as support for signal flow diagrams. Also, maintenance turn-on, MRC repair/replacement and MRC equipment test procedures refer you to the pertinent alignment/adjustment MRCs.

As a group, these MRCs comprise all of the equipment level alignment/adjustment procedures required for the equipment.

GENERAL MAINTENANCE

At the beginning of this chapter, it was noted that you must develop skill and knowledge of a general nature to perform your



SYSTEM SMS	COMPONENT Signal Data Converter, Unit 3/4	MRC CODE 5BBE000 U-2
SUBSYSTEM Radar Set AN/SPG-51D	RELATED MAINTENANCE None	RATES / M/H
MAINTENANCE REQUIREMENT DESCRIPTION 1. Adjust 28 VDC power supply in data converter.		TOTAL M/H ELAPSED TIME:

SAFETY PRECAUTIONS

1. Observe standard safety precautions in accordance with Safety Summary in NAVSEA OP 3541 (PMS/SMS) Volume 1.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. 4" Light duty screwdriver
2. Differential Voltmeter CCUH-803B/AG(SCAT 4208)
3. Stopwatch

PROCEDURE

1. Adjust 28 VDC Power Supply in Data Converter.
   - a. Remove module A15 from data converter.
   - b. Disconnect module power cable by loosening two quick-release fasteners. Extend cable and connect to J1 of module.
   - c. Depress TRACK TRANSMITTER PREHEAT pushbutton indicator on radar set console and verify that the indicator is illuminated.
   - d. Depress TRACK TRANSMITTER STANDBY pushbutton indicator and verify that lower section illuminates immediately and upper section illuminates after 5 minutes.
   - e. Connect meter between A15A6TB1-X8(+) and X9(-).
   - f. Adjust VOLTAGE ADJUST A15A6R11 for an output voltage between +27.9 and +28.1 VDC.
   - g. Disconnect meter.
   - h. Depress TRACK TRANSMITTER OFF/REMOTE CONTROL pushbutton-indicator and verify that the upper section is illuminated.
   - i. Disconnect power cable from J1 of module and reconnect to data converter.
   - j. Reinstall module in data converter.
   - k. Return equipment to normal condition.

PAGE 1 OF 1

B5

CPQB

LOCATION	DATE November 1975

U

MAINTENANCE REQUIREMENT CARD
OPNAV 4790-1 (8) (REV. 3/69)

98.176

Figure 8-11.—Sample unscheduled maintenance MRC.

maintenance tasks. Lubrication, for example, is not explained in detail in your system and equipment OPs, but there are many details with which you should be familiar to perform the task properly. Similarly there are other maintenance actions you will have to accomplish. Therefore, let us discuss some of these general maintenance tasks.

VISUAL INSPECTIONS

You should inspect equipment visually for loose leads, bad connections, damaged or broken components, and the like, before you apply power to the equipment. This applies mainly to equipment that is new, has returned from overhaul, has been stored for long periods of time, or has been exposed to the weather. You should also conduct a close visual inspection of O-rings, gaskets, and other types of seals when the equipment under check is a pressurized component or is exposed to weather. This visual inspection often reveals defects that may be corrected at that time with a minimum amount of labor and parts. Such defects, if left uncorrected, might result in major maintenance problems.

A brief visual inspection should be performed following preventive and corrective maintenance. This might reveal forgotten tools, wires left unconnected after testing, open cover assemblies, and the like.

CLEANING

Cleaning the equipment consists of removing dust, grease, and other foreign matter from the covers, chassis, and operating parts. This includes the removal of corrosion, fungus, and all other types of matter which could cause failure of the equipment. The methods used to clean the parts and units vary, but usually you can use a vacuum cleaner to remove the loose dust and foreign matter. Any remaining matter is then wiped or removed with a clean lint-free cloth. If it is necessary to remove grease or other oily deposits, the cloth may be moistened with a solvent. At times a specific cleaner or solvent may be recommended or a specific one may not be allowed because of its effect on the equipment. After removing the grease, you should either wipe the part or allow it to dry before you apply power.

LUBRICATION

The mechanical parts of electronic equipment are lubricated. Some equipment, such as unsealed bearings, antenna drives, rotating waveguide joints, and the like, may need periodic lubrication. You should lubricate this equipment as directed by the equipment's MRCs.

The specification number of a lubricant should be strictly followed. This is because the thickness of a lubricant changes with a change in operating temperature. That is, high operating temperatures cause lubricants to become thin, while low operating temperatures cause lubricants to thicken.

Detailed procedures for cleaning and lubricating as well as which solvents or lubricants are to be used are provided on MRCs for most applications. Cross-reference guides for solvents and lubricants are available for determining acceptable substitutes. Besides these, no others should be used.

CLEANING AND LUBRICATING ELECTROMECHANICAL COMPONENTS

Many devices used in fire control equipment are highly machined and are close tolerance mechanisms. The accuracy of the fire control system is often dependent upon the operation of these devices. Dirt, dust, or other foreign particles may cause the system to operate with some error. Moisture may cause corrosion which may also result in errors. Excessive wear can cause errors and shorten the life of the equipment. Thus, it can easily be seen that cleaning, lubricating, and drying of close tolerance parts is necessary to have accurate, effective equipment.

Most equipment is enclosed in a dustproof housing. If you use reasonable precautions, the dust problem in this equipment is small. Before you remove a cover, be sure the surrounding area is clean and that all likely sources of dust have been removed. A major source of dust is the ventilation system. When working on precision equipment that is susceptible to dirt and dust, the ventilation system should be secured. If you cannot secure it, cover the blower duct openings with cheesecloth or gauze.

If a unit is removed from its housing and taken to a shop or other working area, adequate provisions must be made to keep the mechanisms clean and dry. Before the unit is disassembled, all dirt, dust, grease, and other foreign matter must be removed from its outside surface. The working surfaces of the unit and the components to be worked on must be as clean and dry as circumstances permit. Whenever the unit is disassembled, all components must be kept under lint-free dust covers (cloths) to protect them from foreign matter.

Even when the precautions just mentioned are taken, some dirt and other foreign matter may get into the equipment. Also, there may be a need to remove excess or old oil and grease. The usual way to remove unwanted oil or grease is with a solvent. Be careful; the correct solvent MUST be used, since some solvents may leave an unwanted residue or cause corrosion. Be sure to check the MRC for the right solvent to use.

Spraying or splashing of the solvent must be avoided during cleaning. If the solvent were to fall upon a bearing surface, it would cut the lubricant or render it less effective. This could cause excessive wear. After the solvent has been used, the parts must always be wiped dry with a clean lint-free cloth.

Lubricants are used to reduce friction between moving parts. Occasionally, lubricants are used for the purpose of preventing rust, oxidation, and corrosion. The applicable MRC includes the lubrication instructions for a specific piece of equipment. However, no lubrication procedure is effective unless it is performed regularly. Different components must be lubricated at different intervals. The approved frequency of lubrication for each component is provided by PMS and must be observed.

Do not apply too much lubricant to your equipment. Excess lubricant acts as an insulation and prevents the dissipation of heat. Overfilling or overheating may cause overflow into adjacent electrical equipment. Lubricants can break down electrical insulation.

Cleanliness is vital in lubrication. Dirt in a lubricant makes a damaging abrasive material. Plastic protective caps are provided for some types of grease fittings. Lubrication points must be cleaned prior to lubrication. If a cleaning solvent is used, the surface to which it is applied must be wiped dry before lubricant is applied.

INSPECTIONS

To lessen the chance of future problems or faults, you must make visual inspections of your equipment. In the following paragraphs, we point out some of the things for which you should look.

Routine visual inspection of terminal boards should be made and terminal screws checked for tightness. Terminal screws tend to work loose due to normal ship vibration. These can cause intermittent faults which may be difficult to find. On the other hand, do not overtighten terminal screws, because the threads may be stripped. Do your best to safeguard against both of these problems.

Cables should be inspected for looseness or damage at places where they enter equipment or at any other point in a cable run. Cables showing signs of damage or abuse should be either rerouted or protected. Special attention should be given to the coaxial cable, which is easily damaged by dents and sharp bends.

Look for signs of overheating and faulty insulation. When these signs appear, the equipment will be blackened around the area of overheating. Check the condition of tubes and tube sockets. Sometimes vibration loosens the tubes in their sockets.

The air screens of amplidyne motors and motor generator sets should be inspected and kept cleared of dirt and dust. Excessive vibration of these units is a danger signal of faulty operation. The usual causes are loose mounting bolts, shaft misalignment, and foreign matter rubbing the rotating element.

Inspect the covers of junction boxes, exposed radar components, and the like, to see that they are properly secured. Tighten all retaining bolts evenly and firmly, alternating between bolts on opposite sides.

ROTATING MACHINERY MAINTENANCE

Rotating machinery (motors, generators, and the like) should be inspected and cleaned according to maintenance schedules and whenever repairs to the machinery have been made. For such cleaning and inspection, the following maintenance hints are provided:

- Dust and dirt can be removed from machine and end covers, using clean, dry, compressed air or a soft brush.

- Be careful not to nick or mar the edges of brushes during removal. Note the location and position from which each is removed so that it can be replaced in exactly the same manner.

- Check commutators or sliprings for excessive wear, pitting, dirt, thrown solder, or other defects. A highly polished commutator or slipring is desirable, but a dark-colored one should not be mistaken for a burned one. Avoid leaving finger marks on the commutator or slipring surface when cleaning.

Sliprings

Sliprings are solid metal rings mounted on the rotor of alternating-current machines. They transfer the power to or from external circuits through brushes or wipers. Sliprings are also used on synchros, director connections, and stable element connections.

While they vary in size and type, the maintenance of sliprings is fairly uniform. They should be inspected regularly for wear, grooving, and cleanliness. Normally, the surface of the rings should be bright and smooth.

As mentioned before, the connection to the rings is by brushes or wipers. Wiper contacts are used with devices that do not require high current and, as a result, require only light pressure when making contact. Too much pressure results in excessive wiper wear, because the wiper contact is usually of a softer material than the rings. Any contacts showing a lot of wear should be replaced.

If sliprings are inspected and found rough, scratched, or grooved, repairs must be made. They can be smoothed with fine crocus cloth or sandpaper. However, care should be used to avoid causing high and low spots which could degrade high-speed operation. Larger repairs, such as cutting with a lathe, should be performed at overhaul activities (Navy yards and tenders). Also, in cleaning with a solvent, be careful not to allow the solvent to enter the bearings, since solvent thins oil or grease. This, of course, would cause the lubricant to flow out of the bearing.

Commutators

Commutators are normally shiny, smoothly worn, and chocolate brown in color. A blackened or pitted commutator is caused by poor brush and segment contact, open or shorted coils, overloads, and the like. If the brushes are causing the blackened appearance, they should be replaced and the commutator should be cleaned. Normally, cleaning is accomplished by the application of a canvas wiper while the machine is running (fig. 8-12).

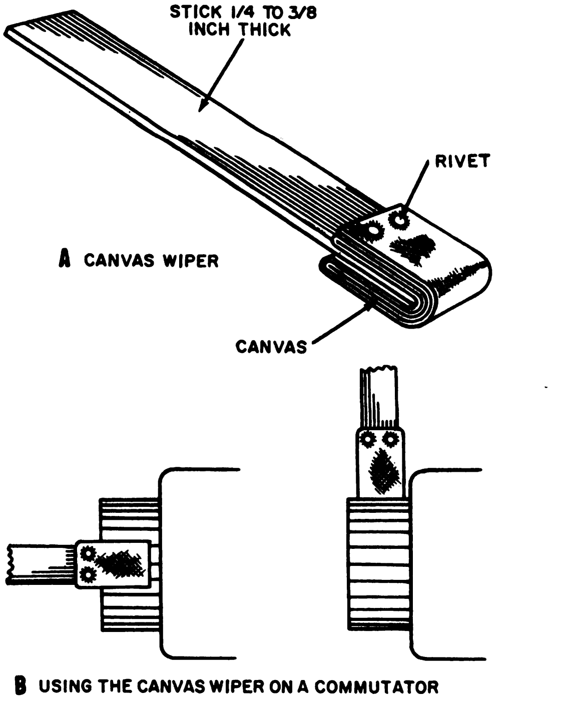

STICK 1/4 TO 3/8 INCH THICK
RIVET
A CANVAS WIPER
CANVAS
B USING THE CANVAS WIPER ON A COMMUTATOR
1.54

Figure 8-12.—Cleaning a commutator.

Under unusual circumstances, such as sparking or excessive brush wear, a fine grade of sandpaper and the recommended solvent can be used. The sandpaper should be held against the commutator by a piece of wood that is grooved to fit the commutator. NEVER USE EMERY CLOTH. Emery is an electrical conductor, which will cause a short circuit.

If the fault is something other than brush and segment contact (for example, a short or open coil), the machine should be replaced and sent to overhaul. Another fairly common defect is high mica. As the copper of the commutator wears down, the mica, which is the insulation separating the segments, does not. Consequently, it may be higher than the segments. The high mica gives a bounce to the brush every time it passes underneath; this results in arcing because the brush is constantly breaking contact. High mica can be spotted by rubbing your fingernail over the surface of the commutator. There should be a small depression between each segment. If there is high mica, this depression disappears. Undercutting is the remedy for high mica, and this operation is normally reserved for overhaul activities.

Brushes

Brushes are found in numerous sizes and shapes and are made of various materials and compounds. Many brushes used in fire control equipment are made of a mixture of graphite and other forms of carbon. It is likely that most of the maintenance you will perform on rotating machinery will have to do with brushes. Brushes should be checked for wear, chipping, oil soaking, sticking in the brush holders, spring tension, length, and area of contact with the commutator. If for any reason a brush is removed and is to be replaced, it should be marked or tagged so it can be replaced in the same position and location it originally occupied.

Brushes that show too much wear or improper wear or chipping, or are oil-soaked, should be replaced. Care should be used in getting the correct replacement. It is important that the brushes be changed before they are completely worn away. This is to prevent damage to the equipment in which they are used.

Some brushes are marked to show allowable wear. A brush of this type has an easy to see groove on its edge. This groove extends from the top of the brush down to a point that is 75 percent of the brush wearing depth. (The top is the end opposite the wearing face.) Thus, if the brush is worn down to the groove, it must be replaced. If no groove is present, consult the equipment OP/TM for acceptable brush lengths.

In the replacement of brushes, you will find that some new brushes are ready to use. That is, the brush face is slightly curved so that it fits tightly on the commutator. If the new brushes are not ready for use, they must be sanded in. This sanding, or seating, can be done by wrapping fine sandpaper around the commutator (fig. 8-13). The paper is placed sand side up with an overlap following the direction of normal rotation of the device, and is held in place by a rubber band. DO NOT use glue or tape. The brushes are placed in their holders under spring tension, and the armature is rotated slowly by hand in the direction of normal rotation. In so doing, the contact surfaces of the brushes are sanded until their curved surfaces

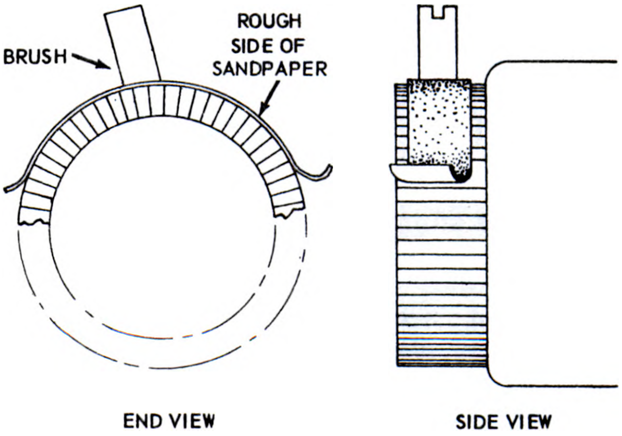


Figure 8-13.—Method of sanding brushes.

match those of the commutator. The carbon dust from the brushes must be removed from the device by using dry compressed air, followed by cleaning with a solvent.

CLEANING OPTICAL LENSES

Cleanliness is extremely important. An optical instrument with components of the highest quality arranged in the best design possible is of little or no value if vision through it is obscured by dirty optics.

The items you will normally need for cleaning optical elements include a small brush (camel's hair), alcohol, lens tissue (soft, lintless paper), and absorbent cotton or silk floss. To this list you may also wish to add a special lintless cloth for cleaning optics. The best type of lintless cloth is velvet.

You will find the following hints useful while cleaning optical devices:

- When brushing the surface of the lens, use quick, light strokes.

- Change cleaning pads or swabs frequently enough to prevent damage to the optic by dirt or grit. Use a cotton, silk, or floss swab, or a lens tissue on small lenses.

- As you clean an optic, swab lightly with a rotary motion, working from the center to the edges. Avoid excessive rubbing. This prevents damage to the coating of an optic and charging it with static electricity.

ENVIRONMENTAL PROBLEMS

You should be aware of certain environmental factors that can have an effect on the operation of fire control equipment. These factors include temperature, humidity, foreign matter, and corrosion.

TEMPERATURE

Very low temperatures may cause brittleness in certain types of metals, and loss of flexibility to rubber, insulation, and like materials. Very high temperatures may cause terminal boards, seals, insulation, and heat-sensitive devices to warp and become brittle. Rapid changes of temperature may be especially damaging to certain types of electronic components.

The cooling or heating of air spaces surrounding the components of electronic equipment is generally accomplished and controlled by blowers, fans, hot oil, water coolers, and the like. These methods are used to dissipate the heat generated by the equipment components, or to control the temperature of the surrounding air. It does not matter what method is employed for the cooling or heating of spaces. If personnel neglect to keep the screens, filters, fans, ducts, and surface area of cooling and heating equipment free from foreign matter, the heating or cooling will be greatly affected. This may result in equipment damage which you may have to correct.

HUMIDITY

Humidity, the measure of water content in the air, is a possible cause of equipment or component failure. High humidity (that is, a high water content in the air) provides a possible environment for corrosion and fungus growth. A high moisture content in the air also may cause a short circuit (arc) between points of high potential.

Arcing is likely to occur in waveguides. To reduce the possibility of arcing, the waveguide and the components connected to it are pressurized with air. This air may be dried by passing it through silica-gel crystals or by the ship's dry-air system, as discussed in chapter 6 of this manual.

In certain cases, the removal of heat from equipment requires the use of external air. If this external air has a high moisture content, the cooling may be accomplished in one of two ways. The high humidity air may be directed through an air jacket which surrounds the equipment. In this case, the heat is removed without allowing the humid air to come in contact with the internal equipment components. In the second method, if the equipment requires direct air for heat removal, the direct air is passed through silica-gel crystals, which absorb the moisture. It should be noted that the second method is less troublesome, because the first may still cause corrosion within the air jacket.

Pressurization is usually not a big maintenance problem, but its loss may cause trouble. The troubles that do arise in the pressurized system are usually the result of poor preventive maintenance. To have a trouble-free pressurized system, all seals and gaskets (located at coupling points, waveguide joints, and case covers) must be very carefully installed to provide an airtight seal. When pressure troubles do occur, they may be hard to detect, since a very small leak is all it takes to render the system inoperable. Before attempting to put the system under pressure to check for leaks, first consult the applicable equipment OP/TM. This is necessary, since each system has certain limits on the amount of pressure that may be safely applied to it. If too much pressure is applied, it could possibly rupture the seals or gaskets, or cause other damage to parts of the equipment.

FOREIGN MATTER

Sand, dust, and other foreign substances which are abrasive in nature affect many components. Generally, these components are parts that are not sealed off from atmospheric conditions. In some equipment, however, the abrasive material is formed even though the unit is sealed. This is true in generators and motors which use brushes. Also, the protective coating on equipment may be removed by the movement of abrasive material in the air that is used for cooling and/or heating. Removal of this coating may allow the exposed metal to corrode.

The use of air conditioning systems with modern equipment minimizes the undesired effects of abrasives, as well as of temperature and humidity. The outside air is only used to cool a heat exchanger. The internal air that removes heat from the equipment then stays relatively clean.

CORROSION

The need for corrosion control has become a major concern in the maintenance of fire control systems. This is because corrosion destroys equipment and is active 24 hours a day.

Moisture Prevention

The battle against moisture is never-ending. Moisture creeps into even the smallest openings. Watertight covers must be kept watertight. When you remove a cover, check the condition of the gasket, the knife edge, and the securing bolts or dogs. Where possible, when checking an electrical circuit, pick a test point in a connection box that is located in a protected space. When moisture is discovered in an energized instrument or connection box, dry it out with a hot-air blower or an electric lamp after turning off the equipment.

A certain degree of protection against the accumulation of moisture is obtained by energizing the equipment daily. Changes in temperature cause air to be breathed through any opening or vent in the equipment. As the air cools, condensation or sweating takes place. Electrical heaters are installed in some equipment to eliminate this source of moisture. The heater keeps the interior of the equipment at a temperature higher than that of the surrounding air. In some equipment, the circuit to the heater bypasses the power switch, and VOLTAGE MAY BE PRESENT EVEN THOUGH THE POWER SWITCH IS OFF. Remember this when working around the heater circuit.

Some equipment may use an air dryer or desiccant unit to remove moisture from the components. The equipment is sealed by dust covers and is airtight except for the connection to the air dryer. The air dryer consists of a unit that contains silica-gel crystals to absorb moisture from the air within the equipment.

Salt and Fungus Treatment

Salt and fungus found in your equipment should be removed at once. Salt, when moisture is present, corrodes metals and conducts electricity. Fungus growth causes decay, rapid breakdown of insulating materials, and shorts or grounds in electrical circuits. In some cases, you can use fresh water to remove the salt. After cleaning the equipment, however, make sure the water has completely evaporated. An approved cleaning solvent may be used to clean away salt or fungus. Pay particular attention to the listed procedures to be followed for the solvent's use. PMS cards and technical manuals will list the proper cleaning agent to be used.

SAFETY PRECAUTIONS

Much has been written on safety precautions. As a result, the number of accidents which occur in the Navy is small. Most of the safety precautions applicable to missile fire control technicians are published in system and equipment OPs. Many of the safety regulations included in these OPs and other technical manuals are the result of actual experiences, so give them careful thought.

CAUSES OF ACCIDENTS

There are four closely related causes of accidents: carelessness, inexperience, overconfidence, and fatigue. Each should be kept in mind.

Carelessness

Carelessness is something most human beings have to overcome. You have to cultivate good working habits—you must learn to coordinate your mental and physical actions to a point where you can concentrate on the important parts of the job at hand without having to worry about the minor, routine functions pertaining to it.

Inexperience

Inexperience can be the cause of accidents no matter how careful the individual intends to be. One way to avoid this problem is NEVER GUESS. You must learn to ask questions about things with which you are not familiar or about which you are not completely sure. Beginners have a tendency to be overeager and desire to put their hands to work. Eagerness is a good trait in any person, but you must realize that individuals with more experience usually know best. Work into a job step by step and be very thorough. Always be conscious of correct procedures in doing things. Train your mind and hands to function correctly so as to protect yourself and others from physical injury. If yo practice correct methods from the start, the will become automatic before you realize it.

Overconfidence

Overconfidence can come to both the youn and old, experienced and inexperienced; it i usually most closely linked with th inexperienced. Often, though, individuals gro overconfident when they become thoroughl familiar with a particular job, and have tendency toward carelessness. To put it briefl always be confident that you know a job, bu beware of overconfidence because it may invit mistakes which can cause accidents.

Fatigue

Fatigue often has been the cause accidents. You might be highly efficient whe you have energy to burn, but it is another stor when you get tired. Your reactions slow dow and become sluggish. Always prepare yoursel for the task ahead by learning how much energ it requires, and then get the proper amount sleep, recreation, food, and exercise to keep yo on your toes. Remember! To be alert and to fee your best is extremely important on the job, an you can enjoy this feeling only by keepin yourself in good physical condition.

ELECTRIC SHOCK

The possibility of accidental electric shock often present in an FT's work. Electric shoc may cause burns of varying degree. It can knoc you unconscious, stop your breathing, stop you heart, and even cause death. If a 60-hert alternating current is passed through a perso from hand to hand or from hand to foot, th effects when current is gradually increased fro zero are as follows:

- At about 1 milliampere (0.001 ampere the shock is felt.

- At about 10 milliamperes (0.01 ampere the shock is severe enough to paralyze muscle and a person may be unable to release th conductor.

- At about 100 milliamperes (0.1 ampere) the shock is usually fatal if it lasts for 1 second or more. IT IS IMPORTANT TO REMEMBER THAT, FUNDAMENTALLY, CURRENT, RATHER THAN VOLTAGE, CONTROLS THE SHOCK INTENSITY.

It should be clearly understood that the resistance of the body varies. That is, if the skin is dry and unbroken, the body resistance will be quite high, on the order of 300,000 to 500,000 ohms. However, if the skin becomes moist or broken, the body resistance may drop to as low as 300 ohms. Thus, a potential as low as 30 volts could cause a fatal current flow. Therefore, any circuit with a potential in excess of this value must be considered dangerous.

> IT SHOULD BE NOTED AT THIS POINT THAT TO INTENTIONALLY CAUSE SHOCK IS PROHIBITED BY NAVAL REGULATION.

Care of Shock Victims

Electric shock is a jarring, shaking sensation resulting from contact with electric circuits or from the effects of lightning. The victim usually experiences the sensation of a sudden blow, and, if the voltage is high enough, unconsciousness. Severe burns may appear on the skin at the place of contact. Muscle spasms can occur, causing a person to clasp the equipment or wire which caused the shock and to be unable to turn loose. Electric shock may sometimes damage nerve tissue and result in a slow wasting away of muscles that may not become apparent until several weeks or months after the shock is received.

The following procedure is recommended for rescue and care of shock victims.

1. Remove the victim from electrical contact at once, but DO NOT ENDANGER YOURSELF. This can be done by:

    a. Turning off the power switch, if it is nearby.

    b. Using a dry stick, rope, leather belt, coat, blanket, or any other nonconductor to pull the victim free (even the victim's shoes can be used).

2. If the victim is not breathing, yell for help and apply artificial respiration without delay. Do this even if the victim appears to be lifeless.

3. Send for a medical officer at once and do not leave the victim until proper medical care has arrived.

4. Keep the victim lying down in a comfortable position. Loosen the clothing about the neck, chest, and abdomen to allow free breathing. Ensure that the victim is protected from the cold and watched carefully. Do not give the victim any drugs.

Cardiopulmonary Resuscitation (CPR)

A person who has stopped breathing is not necessarily dead, but is in immediate, critical danger. For a few minutes, there is some chance that the person's life may be saved. The best treatment for this respiratory failure is mouth-to-mouth ARTIFICIAL VENTILATION (respiration).

If the person has no heartbeat, CARDIAC ARREST has occurred. Stoppage of the heart is soon followed by respiratory failure, if it hasn't occurred first. A person who has no heartbeat must be given external cardiac (heart) massage immediately. Caution must be observed because CPR should not be attempted by a person who is not trained in the proper procedure.

Details on these procedures can be found in the *Standard First Aid Training Course*, NAVEDTRA 10081 series, and in chapter 300 of the *Naval Ships Technical Manual* (NSTM). It is in the interest of every technician to be familiar with these procedures.

GENERAL SAFETY PRECAUTIONS

Although many specific safety precautions are laid down for you in the OPs and technical manuals, there are a few general precautions which you should remember. Let us start by discussing the use of handtools and power tools.

Handling Tools and Machinery

Many accidents occur because of the improper handling of tools. In general, these accidents occur in the form of physical injury to the person operating the tools. The following list gives the more important general precautions to follow:

- Before working with any hand or electric powered tool, inspect the tool to ensure it is in proper condition. Also check any safety equipment that the tool requires.

- Whenever chipping, buffing, or grinding with handtools or power tools, always wear goggles as a protection to the eyes. Little chips from a spinning grind wheel, or a bristle from a revolving wire brush can easily put out an eye. Many of these machines are provided with a safety guard; be sure to use it.

- Always ground the lead provided at the plug of portable tools such as electric drills to protect yourself from shock in case a ground occurs within the tool.

- When working with sharp handtools, always work so that the tool is moved or thrust away from the body.

- Never wear loose clothing or a neckerchief when working with rotating tools or machinery. Such clothing may become caught in the spinning parts and drag you bodily into the machine, causing severe physical injury.

- Never use metal handtools on energized electrical equipment or circuits. You may get shocked, or the tool may produce a short circuit causing molten copper to be blown into your face and eyes.

- Never use handtools around operating machinery, nor perform adjustments to that machinery unless absolutely necessary.

- Never lay a handtool on top of operating machinery where vibration may cause the tool to fall into exposed working parts.

- If it is necessary to work on electric equipment that is in an energized state, wear rubber gloves, use tools with insulated handles, and stand on an insulated mat. Always work with one hand to prevent the chance of a circuit through your body from arm to arm.

- When working with tools, always work in a comfortable position, and keep the weight of your body well centered.

Electrical Work

The following list is an addition to those precautions on handtools and machinery discussed previously, and is applicable to all electrical work. This list will help you prevent electric shock or burns during daily work.

- Do not bypass high-voltage interlocks on doors or covers to keep the circuit energized with the cover off. It is intended that the circuit be deenergized while work is performed on such electrical or electronic equipment.

- Always be sure that all capacitors are fully discharged before commencing work on a deenergized high-voltage circuit. Use a safety shorting probe for this purpose.

- Become familiar with and always observe the standard procedures for tag-out of electrical equipment. This includes the proper use of caution and danger tags and the tag-out log.

- When possible, remove the fuses protecting the circuit you are working on and place them in your pocket for safe-keeping until the job is complete.

- Always remove fuses with fuse pullers. Never remove fuses until after opening the switch that connects the circuit to the source of supply. Never replace a fuse with one larger than the circuit is designed to take.

- Utmost caution should be observed when inspecting behind an open-back switchboard that is energized.

- Always test a supposedly deenergized circuit with a voltage tester before commencing work on the circuit.

- Never work on an electric circuit or network without first thoroughly acquainting yourself with its arrangement and with its points of power feed.

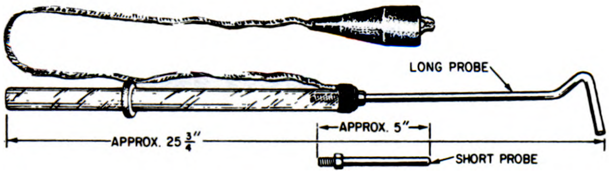
- Never work alone on electrical equipment. Always have someone present to render first aid in case of emergency.

Common Safety Features in Electronic Equipment

You should be aware of the safety features that are generally included in electronic equipment. Some of the common safety features are interlock switches, bleeder resistors, current-limiting resistors, insulating controls, and powerline safety devices such as fuses. Keep in mind that these features cannot always be counted on to function. Do not develop a false sense of security just because a piece of equipment has safety features.

Safety Shorting Probe

ALWAYS ASSUME THAT THERE IS A VOLTAGE PRESENT when working with circuits having high capacitance, even when the circuit has been disconnected from its power source. Capacitors in such circuits should be discharged individually, using an approved type of shorting probe. Large capacitors may retain their charge for a considerable period of time after having been disconnected from a power source. An approved type of shorting probe is shown in figure 8-14 and described in the *Electronics Installation and Maintenance Book*, NAVSEA 0967-LP-000-0100.



1.1

Figure 8-14.—Safety shorting probe.

When using the safety shorting probe, always be sure to first connect the test clip to a good ground (if necessary, scrape the paint of the grounding metal to make a good contact). Then hold the safety shorting probe by the insulated handle and touch the probe end of the shorting rod to the point to be shorted out. The probe end is made so that it can be hooked over the part or terminal to provide a constant connection. Always take care not to touch any of the metal parts of the safety shorting probe while touching the probe to the exposed "hot" terminal. It pays to be safe; use the safety shorting probe with care.

Some equipment units are provided with walkaround shorting (such as fixed grounding studs or permanently attached grounding rods). When this is the case, these features should be used in addition and prior to the safety shorting probe described previously.

RADIOACTIVE ELECTRON TUBES

Electron tubes containing radioactive material are now commonly used. These tubes are known as tr, atr, pre-tr, spark-gap, voltage-regulator, gas-switching, and cold-cathode gas-rectifier tubes. Some of these tubes contain radioactive material and have intensity levels which are dangerous. They are so marked in accordance with military specifications (fig. 5-31).

So long as these electron tubes remain intact and are not broken, no great hazard exists. However, if these tubes are broken and the radioactive material is exposed or escapes from the confines of the electron tube, the radioactive material becomes a potential hazard. For this reason, personnel working with equipment that uses radioactive electron tubes should become thoroughly familiar with the safety precautions for the handling, storage and disposal of these tubes.

CATHODE-RAY TUBES (CRTS)

Cathode-ray tubes should always be handled with extreme caution. The glass envelope encloses a high vacuum and, because of its large surface area, is subject to considerable force caused by atmospheric pressure. (The total force on the surface of a 10-inch crt is 3,750 pounds, or nearly 2 tons; over 1,000 pounds is exerted on its face alone.) Proper handling and disposal instructions for a crt are as follows:

- Avoid scratching or striking the surface.
- Do not use excessive force when removing or replacing the crt in its deflection yoke or its socket.
- Do not try to remove an electromagnetic type of crt from its yoke until the high voltage has been discharged from its anode connector.
- Never hold the crt by its neck.
- Always set the crt with its face down on a thick piece of felt, rubber, or smooth cloth.
- Always handle the crt gently. Rough handling or a sharp blow on the service bench can displace the electrodes within the tube, causing faulty operation.
- Safety glasses and gloves should be worn when handling crts.

CLEANING SOLVENT

The Navy does not permit the use of gasoline, benzine, ether, or like substances for cleaning purposes. Only nonvolatile solvents should be used to clean electrical or electronic components.

In addition to the potential hazard of accidental fires, many cleaning solvents are capable of damaging the human respiratory system in cases of prolonged breathing. The following is a list of "DO NOTs" when using cleaning solvents.

- DO NOT work alone in a poorly ventilated compartment.
- DO NOT breathe directly the vapor of any cleaning solvent for any extended period of time.
- DO NOT spray cleaning solvents on electrical windings or insulation.
- DO NOT apply solvents to warm or hot equipment, since this increases the toxic hazard.

The following reminders are positive safety steps to be taken when cleaning operations are underway.

- Use a blower and a canvas wind chute to blow air into a compartment in which a cleaning solvent is being used.
- Place a fire extinguisher close by, ready for use.
- Use water compounds in place of other solvents when possible.
- Wear rubber gloves to prevent direct contact.
- Use only the solvent listed in the procedure.
- Use goggles when a solvent is being sprayed.
- Hold the nozzle close to the object being sprayed.

AEROSOL DISPENSERS

There are approved procedures for handling and disposing of aerosol dispensers that contain cleaning sprays. Neglecting these procedures can result in serious injury to personnel. These injuries can be caused by toxic fumes, fire, or explosion.

Since there are so many types of aerosol sprays, safety precautions for their handling are not detailed here. However, anyone using these sprays should become familiar with the hazards involved. All safety measures that pertain to their use should be followed. The hazards and proper measures to take for each type of spray can be found on the dispenser label. READ AND HEED!

SAFETY IS YOUR JOB—DO IT PROPERLY!

APPENDIX I

FIRE CONTROL SYMBOLS

PART A—BASIC SYMBOLS. AI-3

PART B—BASIC SYMBOL MODIFIERS AI-6

PART C—QUANTITY MODIFIERS AI-8

PART A

BASIC SYMBOLS

Symbol	Name	Meaning when used alone
B	Bearing of LOS	The relative bearing of the target measured from the vertical plane through own ship centerline to the vertical plane through the line of sight in the horizontal plane clockwise from own ship centerline.
Bm	Bearing of LSM	The relative bearing of the missile measured from the vertical plane through own ship centerline to the vertical plane through the line of sight to the missile in the horizontal plane clockwise from own ship centerline.
mB	Bearing of LMT	The relative bearing of the target measured from the vertical plane through the missile centerline to the vertical plane through the missile line of sight in the horizontal plane clockwise from the missile centerline.
C	Course of target from own ship	The course of the target from the north-south vertical plane to the vertical plane through the relative target speed vector in the frame used by the fire control system, measured in the horizontal plane clockwise from north.
Cm	Course of missile from own ship	The course of the missile from the north-south vertical plane to the vertical plane through the missile speed vector relative to own ship in the frame used by the fire control system, measured in the horizontal plane clockwise from north.
mC	Course of target from missile	The course of the target from the north-south vertical plane to the vertical plane through the target speed vector relative to the missile in the frame used by the fire control system, measured in the horizontal plane clockwise from north.
D	Rate of	The differentiating operator ***d/dt***.
E	Elevation of LOS	The elevation of the target above the horizontal plane measured upward from the horizontal plane in the vertical plane through the line of sight.
Em	Elevation of LSM	The elevation of the missile above the horizontal plane measured upward from the horizontal plane in the vertical plane through the line of sight to the missile.
mE	Elevation of LMT	The elevation of the target above the horizontal plane measured upward from the horizontal plane in the vertical plane through the missile line of sight.
Ei	Level from LOS	The angle between horizontal plane and the deck plane, measured downward from the horizontal plane (on the target side of own ship) in the vertical plane through the line of sight.

Symbol	Name	Meaning when used alone
Eim	Level from LSM	The angle between the horizontal plane and the deck plane, measured downward from the horizontal plane (on the missile side of own ship) in the vertical plane through the line of sight to the missile.
mEi	Level from LMT	The angle between the horizontal plane and the missile deck plane, measured downward from the horizontal plane (on the target side of the missile) in the vertical plane through the missile line of sight.
F	Missile offset angle	The angle between the line of sight to the missile and the line of sight.
G	Gyro angle	
mG	Crossing angle	The angle between the line of sight and the missile velocity vector.
I	Angle of inclination	Only useful as a rate. ***DI*** expresses the rate of rotation of own ship with respect to the earth frame.
mI	Angle of missile inclination.	Only useful as a rate. ***DmI*** expresses the rate of rotation of the missile with respect to the earth frame.
K	Arbitrary constant	
L	Sight deflection from LOS	The total lead angle between the line of sight and the line of fire.
Lm	Sight deflection from LSM.	The total lead angle between the line of sight to the missile and the line of fire.
M	Linear movement	The total linear displacement of the target during the time of flight due to relative motion between own ship and target in the frame used by the fire control system.
mM	Relative guidance displacement.	The total linear displacement of the target during a given time with respect to missile.
P	Launcher parallax base length.	The total linear displacement between the reference point and the launcher measured along the launcher parallax base line.
Pm	Guidance radar parallax base length.	The total linear displacement between the reference point and the guidance radar measured along the guidance radar parallax base line.
Ps	Tracking radar parallax base length.	The total linear displacement between the reference point and the tracking radar measured along the tracking radar parallax base line.

Symbol	Name	Meaning when used alone
Q	Radar phasing order	The angle between the projection of the guidance radar vertical on the boresight plane and the projection of the missile vertical on the boresight plane measured about the line of sight to the missile.
R	Range along LOS	The distance between own ship and target measured along the line of sight.
Rm	Range along LSM	The distance between own ship and missile measured along the line of sight to the missile.
mR	Range along LMT	The distance between missile and target measured along the line of sight from missile to target.
S		
T	Time	Elapsed time.
U	Speed	The nominal speed of the missile with respect to the air mass.
V	Sight angle from LOS	The difference in elevation between the line of sight and the line of fire measured in a vertical plane.
Vm	Sight angle from LSM	The difference in elevation between the line of sight to the missile and the line of fire measured in a vertical plane.
W	Wind rate	The total rate of the true wind measured with respect to the earth.
Z	Cross level about LOS	Angle between the vertical plane through the line of sight, and the normal-to-deck plane through the intersection of the vertical plane through the line of sight and the horizontal plane, measured about an axis which is the intersection of the vertical plane through the line of sight and the horizontal plane.
Zm	Cross level about LSM	The angle between the vertical plane through the line of sight to the missile, and the normal-to-deck plane through the intersection of the vertical plane through the line of sight to the missile and the horizontal plane, measured about an axis which is the intersection of the vertical plane through the line of sight to the missile and the horizontal plane.
mZ	Cross level about LMT	The angle between the vertical plane through the missile line of sight, and the normal-to-missile-deck plane through the intersection of the vertical plane through the missile line of sight and the horizontal plane, measured about an axis which is the intersection of the vertical plane through the missile line of sight and the horizontal plane.

PART B

BASIC SYMBOL MODIFIERS

Modifier	Name	Used to indicate
b	Bearing	Quantities in direction affecting bearing.
c	Computed	Quantities as computed.
d	Deck	Quantities measured in, from, or about axes in the deck.
e	Elevation	Quantities in direction affecting elevation.
f	Flight	Quantities related to weapon flight through the air.
g	Launcher	Quantities measured from, to, or about line of launch or launcher.
h	Horizontal	Quantities measured in horizontal plane.
i		
j		
k	Earth	Quantities expressing earth rates, or measured with respect to the earth.
l		
m	Missile	As a suffix to a basic symbol, quantities measured from, to, or about line of sight to the missile or guidance radar; as a prefix to a basic symbol, quantities measured from missile, to or from or about missile line of sight.
n	Nutational	Quantities relating to the nutation of the radar beam.
o	Own ship	Quantities measured from, to, along, or about own ship or missile centerline, and quantities expressing own ship or missile rates, when used with appropriate prefix.
p	Prediction	
q	Heading	The compass head of own ship, missile, or target.
r	Range	Quantities in direction affecting range.
$\overline{\mathbf{rs}}$	Roll stabilized	Quantities measured in, from,or to the roll stabilized plane.

Modifier	Name	Used to indicate
s	Line of sight	Quantities measured from, to, or about line of sight or tracking radar.
t	Target	Quantities measured from, to, or about target centerline and quantities expressing target rates.
u		
v	Vertical	Quantities in vertical direction.
w	Wind	Quantities related to wind.
x	East-West	Quantities measured in East-West direction.
y	North–South	Quantities measured from North or in North–South direction.
z	Cross level	Quantities related to cross level.
'	Prime	Before quantity, measurement from a normal-to-deck or-to-missile-deck plane; after quantity, measurement to or in a normal plane.
''	Double Prime	Before quantity, measurement from a plane normal to the slant plane; after quantity, measurement to or in a plane normal to the slant plane.
1	Order	Ordered quantities.
2	Future position	Quantities measured with respect to future target position.
3	Launching Position	Quantities measured at instant of launch.
4	Aiming position	Quantities measured with respect to aiming position.
5	Fuze	Quantities used in fuze computations.
6	Capture position	Quantities measured with respect to capture target position or missile capture position, or at time of capture.
(())	Double parentheses	Quantities measured in a system of three indeterminate coordinates.

PART C

QUANTITY MODIFIERS

These modifiers are used before or after parentheses.

Modifier	Name	Before the parentheses	After the parentheses
a			
b	Ballistic	The portion of the quantity accounting for superelevation or drift.	The quantity corrected for the effect of superelevation or drift.
c	Computed, generated, or smoothed	The value of a quantity as computed or generated in the mechanism.	The value of a quantity as smoothed in the mechanism.
d	Designated	The designated value of the quantity.	No meaning.
e	Error	An error of the quantity.	No meaning.
f	Function	A function of the quantity.	No meaning.
g	Dead time	The correction to the quantity due to dead time.	The quantity corrected for the effect of dead time.
h	Missile	No meaning.	The quantity referred to a frame rigidly attached to the missile.
i	Increment	An increment of the quantity.	No meaning.
j	Computational addition or partial	A computational addition to the quantity.	A partial value of the quantity.
k	Earth	No meaning.	The quantity referred to the earth frame.
l	Initial	The initial value of the quantity.	No meaning.
m	Relative motion	The portion of that quantity accounting for relative motion between own ship and target.	The quantity corrected for effect of relative motion between own ship and target.
mg	Crossing angle	The portion of that quantity accounting for angular velocity of the line of sight to missile.	The quantity corrected for the effect of angular velocity of the line of sight to the missile.

Modifier	**Name**	**Before the parentheses**	**After the parentheses**
n			
o	Observed or measured	The observed or measured value of the quantity.	Referred to a frame rigidly attached to own ship.
p	Launcher parallax	The portion of the quantity accounting for launcher parallax.	The quantity corrected for the effect of the launcher parallax.
pm	Guidance beam parallax	The portion of the quantity accounting for guidance beam parallax.	The quantity corrected for the effect of guidance beam parallax.
ps	Tracking director parallax	The portion of the quantity accounting for tracking director parallax.	The quantity corrected for effect of tracking director parallax.
q	Corrective input, spot, or bias	A correcting input, spot, or bias to the quantity.	No meaning.
r	Rotational	The correction to a quantity due to launcher rotational velocity.	The quantity including the correction for launcher rotational velocity.
s	Selected	A selected value of the quantity.	Referred to the inertial frame.
t	Translational	The correction to a quantity due to launcher translational velocity.	The quantity including the correction for launcher translational velocity.
u	Unclear	Angular or other coordinates not clear for various reasons (left angle limit).	Angular or other coordinates not clear for various reasons (right angle limit).
v			
w	Wind	The portion of the quantity accounting for the effect of the wind.	The quantity corrected for the effect of the wind.
x			
y			
z			

APPENDIX II

GLOSSARY

ACCELEROMETER.–An instrument that measures one or more components of the changes in speed of a moving body in which the instrument is contained.

ACQUISITION.–The location, lock-on, and commencement of automatic tracking of a target by a fire control radar.

AERODYNAMICS.–The science that deals with the motion of air and other gasses and with the forces acting on bodies moving through these gasses.

AIRFRAME.–The main structure of an aircraft or missile. It includes the framework and skin but not the engines or internal components.

ASPHYXIA.–The lack of oxygen or excess of carbon dioxide that causes unconsciousness and subsequently death.

ASPHYXIATION.–The loss of consciousness due to a lack of oxygen or an excess of carbon dioxide in the blood.

ATTITUDE, MISSILE.–The position of a missile as determined by the inclination of its axes to its designed frame of reference.

AUTOPILOT.–A system that detects deviations in the flight of an aircraft and applies the required corrections to the steering controls. Also called automatic pilot.

BATTERY ALIGNMENT.–Alignment of weapons and fire control equipment to a common system of reference lines and planes under specified conditions.

BEAM-RIDER.–A missile that follows a radar or other rf energy beam directed at the target.

BEAT FREQUENCY.–One of the two additional frequencies produced when two different frequencies are combined. One of these beat frequencies is the sum and one is the difference of the two original frequencies.

BOOSTER.–An auxiliary or initial propulsion system which travels with a missile or aircraft and which may or may not separate from that craft when its impulse has been delivered.

BOOST PHASE.–The initial portion of a missile's flight during which it attains its flight speed.

BUS.–A heavy rigid metallic conductor used to carry a large current or to make a common connection between several circuits. Also called bus bar.

CANISTER (LAUNCHER).–A replaceable cylindrical shell structure that contains the launch rail and acts as a storage magazine.

CANNIBALIZE.–To remove usable parts from one piece of equipment for use in repairing another piece of equipment.

CARDIOPULMONARY RESUSCITATION (CPR).–The collective term for restoring breathing and/or the heartbeat of a person.

CHAFF.—Bits of radar reflective material such as metal foil, that are released in the air to mask the flight of an aircraft or confuse and clutter the radar picture.

CHIP.—Another name for an integrated circuit.

CLUTTER.—Radar return from rain, clouds, land, sea, or other unwanted objects.

COLLIMATION.—The precise alignment of the mechanical system of a radar antenna, by comparison with an optical device aligned on known points in bearing and elevation.

CONAR.—Acronym for commanding officer's narrative report.

CONICAL SCAN ON RECEIVE ONLY (COSRO).—A radar feature which, instead of physically scanning the antenna beam on transmission to derive target angle information, processes (or scans) the received signal to derive angle data.

CONTINUOUS WAVE ILLUMINATOR (CWI).—Provides target illumination for semiactive homing missiles. Continuous wave refers to the continuous transmission of the illumination beam.

CRUISE MISSILE.—Guided missile, the major portion of whose flight is at an approximately constant velocity.

DATA LINK.—Equipment for automatically transmitting and receiving information in digital form.

DCAP.—Acronym for Deficiency Corrective Action Program.

DESICCANT.—A drying agent (as silica gel or calcium chloride).

DESIGNATION, TARGET.—The selection of targets which are to be engaged, and transmission of the position information required for acquisition by the fire control radar or radars.

DISH.—A parabolic reflector (slang).

DOPPLER EFFECT.—Frequency shift of a radiated signal (sound or radio) due to the relative motion between the source and the receiving point.

DOWN LINK.—Radio communication from a missile to its control or launching point. It normally contains flight information.

DSOT.—Abbreviation for Daily System Operability Test.

DUD/DUDDING.—Internal malfunctioning of a missile that prevents proper execution of all phases of missile launching and flight.

DUMMY LOAD.—A device used at the end of a transmission line or waveguide that converts the rf energy into heat and dissipates it. In this way, no rf energy is radiated out nor reflected back to its source.

DUTY CYCLE.—Ratio of transmitted pulse width to pulse repetition period.

ECHO.—Signal received by a radar as a result of the reflection of a transmitted pulse from objects in the field of scan.

ELECTRONIC COUNTERMEASURES (ECM).—Methods of jamming or otherwise hindering the operation of the enemy's electronic equipment.

ELECTRONIC COUNTER-COUNTERMEASURES (ECCM).—Techniques used to minimize or eliminate the effects of electronic countermeasures.

ELECTRONIC WARFARE SUPPORT MEASURES (ESM).—Actions taken to search for, intercept, locate, record and analyze enemy rf emissions in support of military operations.

ELECTROMAGNETIC INTERFERENCE (EMI).—An effect, usually generated internally, that can, either directly or indirectly, degrade the performance of an electronic receiver or system.

ENGAGEMENT, TARGET.–Collectively, all actions taken to destroy an enemy (target). This may include, but not be limited to, tracking, illumination, and weapon launching and control.

EQUIPAGE.–Supply items that are not consumed in use and are essential to the ship's mission. They are usually portable and/or high cost items.

FAST TIME CONSTANT (FTC).–A differentiating circuit which attenuates long pulse-like clutter or jamming signals by the use of a short time-constant network.

FEEDHORN.–A horn type radiator that is directed into a parabolic reflector.

FUZE.–A device designed to initiate a detonation of a weapon under the conditions desired, such as by impact, elapsed time, proximity, or command.

GATE.–To control the passage of a pulse or signal. Also the circuit that performs this function.

HEIGHT-FINDER.–A radar set that measures and indicates the height of an airborne object.

HEMISPHERICAL SEARCH.–Another term for three-dimensional search (radar).

HOME ON JAM.–A missile mode of operation in which the target's jamming signal is used as the source of guidance information.

HOMING.–A guidance method by which the missile uses radiation from the target to establish a collision course.

HORIZONTAL PLANE.–A frame of measurement that is parallel to the earth's surface at the point of origin.

HORN (ANTENNA).–A microwave antenna produced by flaring out the end of a circular or rectangular waveguide into the shape of a horn, for radiating radio waves.

IDENTIFICATION, FRIEND OR FOE (IFF).–A system of using electronic transmissions as a method of determining whether ships, aircraft, or ground forces are friendly or not friendly. When a signal is sent, friendly forces reply with coded pulses. Enemy forces, of course, do not know the coded pulses, so are readily identified as unfriendly.

ILLUMINATION.–The process of aiming rf energy at a target so that the reflected signal can be used by the missile for guidance information.

INERTIAL GUIDANCE.–A self-contained type of guidance in which the missile senses any deviation in direction, speed, or attitude and automatically compensates for it.

INFRARED.–Electromagnetic radiations (thermal) of wavelengths between that of visible light and microwaves. Guidance system that homes in on heat radiated by the target.

INTERDIRECTOR DESIGNATION (IDD).–The transmission of repeatback information of a director to another director for the purpose of tracking the same target.

INTERFACE.–The interconnecting equipment, including wiring, data converters, switchboards, etc. that enable equipments to establish external communication with other equipments or systems.

JAMMING.–The intentional disruption of the normal operation of a radar or radio system through the use of electromagnetic interference, mechanical devices, and/or deception.

KNOT.–A nautical mile (approx. 2,000 yd) or 1.1516 statute miles per hour. It is not a measure of distance, but of speed.

LINE OF FIRE (LOF).–An imaginary line along which a missile or other weapon is launched.

LINE OF SIGHT (LOS).–An imaginary line from a radar or optical device to a target being tracked.

LOCK ON.–The moment at which a tracking or target seeking system begins automatic tracking of a target in one or more coordinates (e.g. range, bearing, elevation).

MAGAZINE.–The portion of a gun or missile launching system that provides for stowage.

MODULATION.–The process by which some characteristic of one signal is varied in accordance with another signal.

NOISE.–Signals other than and interfering with the signal desired.

NUTATE.–To oscillate through a small angle in a specific pattern.

ORDALT.–Acronym for ordnance alteration. This may consist of minor changes (such as wiring) or major changes (such as new equipment components).

ORDNANCE.–Weapons, and equipment used in their control.

ORIGIN.–The point from which measurements are made, as from the intersection of references on a graph.

O-RING.–A ring (as rubber) used as a gasket.

PARABOLOID.–A reflecting surface formed by rotating a parabola about its axis of symmetry.

PARALLAX.–The angular difference which results from making observations or computations to one target from two different stations. Normally measured in horizontal and vertical planes.

PARAMETER.–Any of a set of physical properties whose values determine the characteristic or behavior of something.

PAYLOAD.–The warhead section in a military missile.

PERFORMANCE ENVELOPE.–The area (range and altitude) that a missile or other weapon can effectively carry out its mission.

PERIODICITY.–The rate at which an event regularly recurs.

PERIPHERAL.–A device connected to a computer to provide communication (as input and output) or auxiliary functions (as papertape reader or line printer.).

PITCH.–Angular displacement, measured in the vertical plane, of the centerline or longitudinal axis of a ship or aircraft.

POLARIZATION.–The direction of the electrical field as radiated from a transmitting antenna, usually either vertical or horizontal.

PRECESS.–To change the orientation of an axis of a gyroscope or other rotating body.

PROPORTIONAL NAVIGATION.–A homing guidance technique in which the missile turn rate is proportional to the turn rate of the missile-to-target line-of-sight.

PULSE WIDTH.–The time duration of the transmission of the pulse of energy, usually measured in microseconds or in the equivalent distance in yards, miles, etc. Also called pulse duration and pulse length.

PULSE REPETITION RATE (PRR).–The number of times per second that a pulse is transmitted. Also called pulse repetition frequency (PRF).

RADAR HORIZON.–The point beyond which objects are not detectable by a radar due to the curvature of the earth.

RADAR SILENCE.–The period of time during which radar transmission is stopped, usually for security reasons.

RADIAL VELOCITY.–Another term for range rate or target speed relative to own ship.

RANGE RATE.–Rate of change of range, usually in yards per second, caused by relative motion of own ship and target.

RECIPROCAL.–Opposite or inversely related, as one of a pair of quantities whose product is one.

REFERENCE PLANE.–An arbitrarily chosen plane from which quantities (usually angles) are measured.

REFRACTION.–Deflection from a straight path undergone by a light ray or energy wave in passing at an angle from one medium (as air) into another (as glass) in which its speed is different.

RELATIVE BEARING.–Directional coordinates referenced to the centerline of the ship with the bow designated as 000 degrees increasing in a clockwise direction through 360 degrees back to the bow.

RESOLUTION.–The minimum separation (in angle or range) between two targets at which they can be distinguished on the radar screen.

ROLL.–The angular rotation of the centerline or longitudinal axis of a ship or aircraft measured in an athwartship vertical plane.

SCOPE.–Term often used to denote a crt type radar indicator or a test oscilloscope.

SEA RETURN.–Clutter on a radar due to reflection of signals by the sea. Also called sea clutter.

SEEKER.–A missile antenna or receiver that finds its target by means of heat, light, radio waves, sound or other radiation coming from the target.

SENSITIVITY TIME CONTROL (STC).–A time-varied gain method of decreasing radar sensitivity at short ranges to reduce the intensity of sea clutter with only slight impairment of sensitivity at long ranges.

SHIPALT.–Acronym for a design change or alteration to nonordnance shipboard equipment.

SIDE LOBES.–Undesirable radiation lobes of a radar antenna. A number of these exist on each side of the main beam in all directions surrounding the main beam.

SLANT RANGE.–The distance between two points that are not at the same altitude, e.g. a ship and an aircraft.

SLIP RING.–A conducting ring mounted on, but insulated from, a rotating shaft, used with a stationary brush to join fixed and moving parts of a circuit (as in a director).

SOFTWARE.–The entire set of programs, procedures, and related documentation associated with a system, esp. a computer system.

SPOOFING.–Jamming that deceives or misleads with target-like signals.

SQUIB.–A small pyrotechnic device used to fire the igniter in a rocket.

STABILIZATION.–Maintenance of a desired orientation independent of the roll and pitch of a ship or aircraft.

STABLE ELEMENT.–Gyroscopic device which maintains a reference horizontal plane.

SUPERELEVATION.–An offset to the launcher's elevation order to compensate for the effect of gravity.

SUSTAINER.–A propulsion system that travels with and does not separate from the missile. The term is usually applied to solid propellant rocket motors when used as the principal propulsion system, as distinguished from an auxiliary motor or booster.

SWEEP.–The steady movement of the electron beam across the screen of a cathode-ray tube, producing a steady bright line when no signal is present.

TELEMETRY.–The process of measuring a quantity, transmitting the result to a distant station, and there indicating or recording the quantity measured.

TERRAIN MATCHING.—Guidance of a missile by means of a radar altimeter recording previously obtained by a reconnaissance flight over the terrain, compared with altimeter readings received during the new flight. Also known as mapmatching.

TMINS.—Abbreviation for the new "Technical Manual Identification Numbering System".

TOLERANCE.—The allowable deviation from a specification.

TRACKING.—Monitoring or following a target's movement, esp. by radar.

TRAJECTORY.—The flight path of a projectile or missile.

TRUE BEARING.—A bearing given in relation to true geographic north.

UPLINK.—Radio communication from a control point to a missile.

VERTICAL PLANE.—A plane perpendicular to the horizontal.

WEAPON-RELEASE RANGE.—The maximum range at which a bomber can launch or release its weapons and strike its target.

X-AXIS.—A horizontal axis in a system of rectangular coordinates; that line on which distances to the right or left (east or west) of the reference line are marked, especially on a map or chart.

Y-AXIS.—A vertical axis in a system of rectangular coordinates; that line on which distances above or below (north or south) the reference line are marked, especially on a map, chart, or graph.

YAW.—To turn by angular motion about the vertical axis as of a ship or aircraft.

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FIRE CONTROL TECHNICIAN M 3

NAVEDTRA 10224

Prepared by the Naval Education and Training Program Development
Center, Pensacola, Florida

Your nonresident career course (NRCC) contains a set of assignments and perforated answer sheets. The Rate Training Manual, FIRE CONTROL TECHNICIAN M 3, NAVEDTRA 10224, is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the questions. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of questions. The learning objectives and questions are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the questions.

At this point you should be ready to answer the questions in the assignment. Read each question carefully. Select the BEST ANSWER for each question, consulting your textbook when necessary. Be sure to select the BEST ANSWER from the subject matter in the textbook. You may discuss difficult points in the course with others. However, the answer you select must be your own. Remove a perforated answer sheet from the back of this text, write in the proper assignment number, and enter your answer for each question.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course, you can complete it successfully by earning a minimum of 3.2 for each assignment. Credit given for the course is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed answer sheet to the officer designated to grade it. The graded answer sheet will not be returned to you.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make an entry in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed answer sheet until you finish all the assignments in the course. Using the envelopes provided, mail your completed answer sheets to the Naval Education and Training Program Development Center where they will be graded and the score recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. The graded answer sheets will not be returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course. To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the book-return form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Occupational Standards for your rating as found in the MANUAL OF NAVY ENLISTED MANPOWER AND PERSONNEL CLASSIFICATIONS AND OCCUPATIONAL STANDARDS (NAVPERS 18068). These Occupational Standards define the minimum tasks required of your rating. The sources of questions in your advancement examination are listed in the BIBLIOGRAPHY FOR ADVANCEMENT STUDY (NAVEDTRA 10052). For your convenience, the Occupational Standards and the sources of questions for your rating are combined in a single pamphlet for the series of examinations for each year. These OCCUPATIONAL STANDARDS AND BIBLIOGRAPHY SHEETS (called Bib Sheets), are available from your ESO. Since your textbook and NRCC are among the sources listed in the bibliography, be sure to study both as you take the course. The qualifications for your rating may have changed since your course and textbook were printed, so be sure you get the Bib Sheets that apply to the specific examination for which you are applying.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 12 Naval Reserve retirement points, which will be credited upon satisfactory completion of the entire course. These points are creditable to personnel eligible to receive them under current directives governing the retirement of Naval Reserve personnel. Credit cannot be given for this course if the student has previously received credit for completing a Fire Control Technician M 3 & 2 NRCC or ECC.

COURSE OBJECTIVE

This course, when completed satisfactorily, will aid the trainee in acquiring the background knowledge necessary to:

1. Identify the purposes and functions of surface missile weapon systems and subsystems including missiles and fire control radars.
2. Test, troubleshoot and repair surface missile system equipment and support systems.
3. Administer surface missile weapon systems by using the proper procedures and documentation provided.
4. Recognize the safety precautions involved with ordnance handling, fire control radar operation and general maintenance.

> While working on this correspondence course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval courses may include a variety of questions -- multiple-choice, true-false, matching, etc. The questions are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of questions, others only a few. The student can readily identify the type of each question (and the action required) through inspection of the samples given below.

MULTIPLE-CHOICE QUESTIONS

Each question contains several alternatives, one of which provides the best answer to the question. Select the best alternative, and blacken the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was
1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-1	☐	■	☐	☐	___

TRUE-FALSE QUESTIONS

Mark each statement true or false as indicated below. If any part of the statement is false the statement is to be considered false. Make the decision, and blacken the appropriate box on the answer sheet.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with any systems command of the Department of the Navy without his commanding officer's endorsement.

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-2	☐	■	☐	☐	___

MATCHING QUESTIONS

Each set of questions consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Items in column B may be used once, more than once, or not at all. Specific instructions are given with each set of questions. Select the numbers identifying the answers and blacken the appropriate boxes on the answer sheet.

SAMPLE

In questions s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A	B
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Disbursing Officer	3. Supply Department
s-6. Communications Officer	

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-3	☐	■	☐	☐	___
s-4	■	☐	☐	☐	___
s-5	☐	☐	■	☐	___
s-6	■	☐	☐	☐	___

Assignment 1

Duties, Background, and Missile Structure

Textbook Assignment: FTM3, NAVEDTRA 10224; pages 1-1 through 2-11

Learning Objective: Define the FT rating and the duties and responsibilities of the FTM.

1-1. The suffixes M, G, and B designate a
_____(a)_____ and apply to FTs
(rating), (service rating)
at the _____(b)_____
(E-7 through E-9), (E-1 through E-7)
levels.

1. (a) Service rating (b) E-7 through E-9
2. (a) Service rating (b) E-1 through E-7
3. (a) Rating (b) E-7 through E-9
4. (a) Rating (b) E-1 through E-7

1-2. Besides being an equipment specialist, you as an FTM3 must have an overall knowledge of which of the following?

1. Missile fire control
2. Naval Enlisted Classification
3. Advancement in rate exams
4. Gunfire support

1-3. Your assignment to a missile fire control system may include which of the following types of work?

1. Operation only
2. Operation and testing only
3. Testing, repair, and alignment
4. Testing, design, and repair

1-4. To which of the following equipment may you be assigned?

1. Weapon direction
2. Support
3. Search radar
4. Each of the above

1-5. Which of the following duties are you NOT required to perform?

1. Repair missile launchers
2. Read wiring diagrams
3. Requisition spare parts
4. Maintain logs

1-6. As an FTM, your range of duties increases as which of the following changes?

1. You get older
2. You get more time in service
3. Your skill and knowledge increases
4. Your desire to advance increases

Learning Objective: Relate events that led to the development of modern fire control.

1-7. The first large scale use of naval guns was by the

1. British
2. Spanish
3. Romans
4. Greeks

1-8. The first gun sights were similar to those still used on what type of weapons?

1. Naval guns
2. Small arms
3. Howitzers
4. Guided missiles

1-9. Who developed the adjustable telescope?

1. A naval officer
2. A gunnery sergeant
3. Marconi
4. Georges Palomar

1-10. What was the first means of determining a target's range?

1. Rangefinder
2. Stadimeter
3. Human eye
4. Computer

1-11. Which of the following devices has been or is being used to establish a fixed reference for measuring elevation angles?

1. Suspended shot
2. Stable element
3. Ship's gyro
4. Each of the above

1-12. The most significant corrections to be made in fire control are for what factor?

1. Gravity
2. Wind
3. Changes in projectile velocity
4. Relative motion between gun and target

1-13. The marking of a target's position on paper as it moves along its course is called

1. plotting
2. rangekeeping
3. computing
4. correlating

1-14. Which of the following devices overcame the shortcomings of optical instruments?

1. Rangekeepers
2. Computers
3. Radars
4. Directors

1-15. Fire control systems are used to control the delivery of which of the following weapons?

1. Guns and missiles only
2. Missiles and rockets only
3. Guns, missiles, and torpedoes
4. Guns, missiles, rockets, and torpedoes

IN ANSWERING QUESTIONS 1-16 THROUGH 1-18, SELECT FROM COLUMN B THE WEAPON SYSTEM COMPONENT THAT PERFORMS THE FUNCTION LISTED IN COLUMN A.

	A. FUNCTION	B. COMPONENT
1-16.	Evaluates targets	1. Radar/director
		2. WDS
1-17.	Provides exact target-position data	3. Launching system
		4. Computer
1-18.	Generates launcher-position signals	

1-19. Which of the following functions is/are provided for by the launching system?

1. Support of missile for firing
2. Aiming the missile
3. Storing the missile
4. All of the above

Learning Objective: State the purpose for the development of guided missiles and list current Navy surface-to-air missiles.

1-20. In military usage, the term missile is synonymous with

1. rocket
2. torpedo
3. guided missile
4. depth charge

1-21. Compared to guns, missiles have which of the following advantages?

1. Cheaper and smaller
2. Cheaper and longer range
3. Longer range and more effective
4. Smaller and faster

1-22. The Navy's first surface-to-air missiles were designed for what purpose?

1. Fleet-wide antiaircraft defense
2. Antiship missile defense
3. Long-range bombing
4. Early warning

1-23. Which of the following missiles is used solely for self-defense at close-in ranges?

1. TARTAR
2. SPARROW III
3. HARPOON
4. TOMAHAWK

1-24. Which of the following is/are (an) anti-ship missile(s)?

1. SPARROW III
2. HARPOON only
3. TOMAHAWK only
4. Both HARPOON and TOMAHAWK

1-25. What missile system is a fully automated, surface-to-air weapon system with short reaction time and high fire power?

1. AEGIS
2. RAM
3. STANDARD
4. TOMAHAWK

Learning Objective: Describe fundamentals of guided missiles in general terms.

1-26. Chapter 2 is based primarily on what type of guided missile?

1. Surface-launched
2. Air-launched
3. Subsurface-launched
4. Land-launched

1-27. The term missile, as defined in this chapter, refers to which of the following?

1. Stones
2. Bombs
3. Rockets
4. Each of the above

1-28. An unmanned vehicle that is capable of altering its course during its flight is classified as a/an

1. self-propelled rocket
2. guided missile
3. projectile
4. unguided missile

1-29. Which of the following is NOT a subsystem of a guided missile?

1. Flight control
2. Guidance
3. Electronics
4. Propulsion

1-30. The main missile structure is known as which of the following?

1. The airframe
2. The body
3. The fuselage
4. Each of the above

Learning Objective: List the basic requirements of a guided missile relating to SMS missiles.

1-31. An aircraft's standoff range is best described as the

1. maximum range at which a guided missile can destroy the aircraft
2. minimum range at which the aircraft can effectively deliver its weapons
3. maximum range at which the aircraft can effectively deliver its weapons
4. minimum range at which a guided missile can destroy the aircraft

QUESTION 1-32 IS TO BE JUDGED TRUE OR FALSE.

1-32. SMS missiles include short-range surface-to-surface missiles.

1-33. Which of the following is NOT primarily a surface-to-air missile?

1. SPARROW III
2. HARPOON
3. SM-1
4. SM-2

1-34. The missile designation RGM-84A indicates a

1. rocket-launched guided missile
2. rocket-launched torpedo
3. ship-launched guided missile
4. ship-launched rocket

1-35. Which of the following missiles is designed for use against a surface target?

1. AIM-7E
2. RIM-66D
3. AQM-74C
4. RGM-84A

1-36. What type of missile is the AQM-74C?

1. Trainer
2. Surface-attack
3. Drone
4. Aerial-intercept

Learning Objective: List the five major missile subsystems and the purpose of each.

1-37. What subsystem of a guided missile (a) furnishes external control surfaces for flight path control action, and (b) contains the element for sensing the optimum time for detonation?

1. (a) Structure, (b) warhead
2. (a) Control, (b) guidance
3. (a) Propulsion, (b) control
4. (a) Guidance, (b) warhead

1-38. What guided missile subsystem (a) maintains the intended speed of the missile, and (b) restrains the missile to its flight path?

1. (a) Propulsion, (b) control
2. (a) Control, (b) structure
3. (a) Structure, (b) guidance
4. (a) Guidance, (b) propulsion

1-39. What subsystem of the guided missile senses missile diversion from its guided flight path and starts the operation to rectify this error?

1. Control
2. Guidance
3. Structure
4. Propulsion

1-40. Which of the following types of guidance is used by most SMS missiles?

1. Beam-rider
2. Homing
3. Command
4. Inertial

Learning Objective: Point out the fundamental characteristics of payloads, fuzes, and safety and arming components used in guided missile warheads.

1-41. Each warhead consists of a payload and what other functional parts?

1. Telemetering unit and fuze
2. Telemetering unit and S&A device
3. Fuze and S&A device
4. Fuze and self-destruct device

1-42. What type of warhead is NOT generally used in guided missiles?

1. Blast-effect
?. Nuclear
3. Thermonuclear
4. Incendiary

QUESTIONS 1-43 THROUGH 1-45 REFER TO THE FOLLOWING LIST OF DESTRUCTIVE EFFECTS OF MISSILE WARHEADS.

A. VIOLENT BURNING
B. A HIGH PRESSURE WAVE
C. FLYING SHRAPNEL
D. BLAST, HEAT, AND RADIATION
E. BLAST PLUS EXPLOSIVE PELLETS

1-43. Destructive effect B results from the detonation of

1. explosive pellet warheads
2. incendiary warheads
3. shaped-charge warheads
4. blast-effect warheads

1-44. Which of the following destructive effects is produced by a fragmentation warhead?

1. B
2. C
3. D
4. E

1-45. Destructive effect D is the major cause of damage resulting from the detonation of

1. atomic warheads
2. incendiary warheads
3. shaped-charge warheads
4. fragmentation warheads

1-46. What type of warhead is most often used in SMS missiles?

1. Blast-effect
2. Uncontrolled-fragmentation
3. Continuous-rod
4. Controlled-blast

1-47. The best time for fuze detonation is determined by the location and movement of which of the following?

1. The firing ship and the target only
2. The firing ship and the missile only
3. The missile and the target only
4. The firing ship, the target, and the missile

1-48. Which of the following pairs of fuzes are of the impact type?

1. Delay and instantaneous
2. Delay and ground-controlled
3. Instantaneous and ground-controlled
4. Instantaneous and radio-controlled

1-49. The term TDD refers to which, if any, of the following types of fuzes?

1. Impact
2. Proximity
3. Ground-controlled
4. None of the above

1-50. What does the S&A device provide for in the warhead?

1. Detonation path only
2. Detonation interrupt only
3. Detonation path and interrupt only
4. Detonation interrupt, path, and amplifier stage

1-51. An acceleration arming device requires which of the following missile motions to arm the warhead?

1. Acceleration only
2. Deceleration only
3. Acceleration and deceleration
4. Acceleration and acceleration decay

Learning Objective: Indicate the functions occurring during the guidance flight phases for SMS missiles.

1-52. Determining flight-path errors and generating necessary correction signals are functions of the

1. receiver
2. control subsystem
3. guidance subsystem
4. control-surface servos

1-53. Which of the following missile attitudes are the missile control units capable of controlling?

1. Roll only
2. Pitch and yaw only
3. Pitch and roll only
4. Pitch, roll, and yaw

1-54. The main function of a missile booster is to

1. provide guidance during the acceleration period
2. propel the missile throughout its flight
3. provide power to accelerate the missile to operating speed
4. propel the missile from the launcher

1-55. What is the function of the boost phase guidance system?

1. To make the homing missile "look" toward the target
2. To keep the missile on its launch heading
3. To allow the missile to capture the guidance beam
4. To help the missile predict where it will be at the end of the boost phase

1-56. During what phase of a missile's flight are most flight corrections made?

1. Launch
2. Midcourse
3. Terminal
4. Dump

1-57. Which of the following is a requirement of the terminal phase of guidance?

1. Maximum maneuverability
2. Fast signal response
3. Great accuracy
4. Each of the above

Assignment 2

Guidance, Missile Systems, and The Weapon Control System

Textbook Assignment: FTM 3, NAVEDTRA 10224; pages 2-12 through 3-15

Learning Objective: Identify different kinds of missile guidance systems including their characteristics.

2-1. Missile attitude control is achieved through which of the following types of guidance?

1. Inertial
2. Command
3. Homing
4. Semihoming

2-2. The inertial guidance system makes use of accelerometers to

1. measure the distance the missile travels
2. detect changes in missile motion
3. Indicate missile speed
4. determine target position

QUESTIONS 2-3 THROUGH 2-5 ARE TO BE JUDGED TRUE OR FALSE.

2-3. Inertial guidance is used only during the boost phase.

2-4. With command guidance, the guidance instructions originate outside the missile.

2-5. With command guidance, the missile has direct electromagnetic contact with the target.

2-6. The command guidance receiver can accept which of the following data?

1. Steering signals only
2. Steering and control signals only
3. Fuze and control signals only
4. Steering, fuze, and control signals

2-7. Command signals are sent to the missile by which of the following methods?

1. Varying the missile tracking beam
2. Varying the guidance beam
3. Using a separate radio uplink
4. Each of the above

2-8. The beam-rider missile is kept in the center of the beam by correction signals generated by the

1. fire control computer
2. fire control radar
3. missile itself
4. guidance beam

2-9. A missile guidance system that can detect and guide itself to a target is called

1. beam-rider guidance
2. homing guidance
3. inertial guidance
4. pre-set guidance

2-10. Homing is the most accurate of all guidance systems for which of the following reasons?

1. Because it can not be jammed
2. Because the target is used as the source for guidance error signals
3. Because it uses a digital computer
4. For all of the above reasons

2-11. A guidance system that illuminates the target by equipment within the missile makes use of what type of homing?

1. Active
2. Semiactive
3. Passive
4. Beam-rider

2-12. Active homing missiles are limited in range by which of the following?

1. Target size
2. Fire control radar output
3. Missile transmitter output
4. Fire control radar sensitivity

2-13. Which of the following is a characteristic of semiactive homing guidance?

1. The missile receives reflections from the target which is illuminated by a radar or other means from outside the target and missile
2. Two radars are used; one to track and illuminate the target and the other to track the missile
3. Once the missile is launched, it functions independently of any outside source
4. The missile contains sufficient guidance equipment to enable it to operate either independently of, or in conjunction with, a controlling radar

2-14. Which of the following statements expresses a disadvantage of the semiactive homing system?

1. Since the delivery vehicle contains the energy transmitter, it cannot engage another target until the missile reaches intercept
2. Since the system requires a transmitter located in the missile, the range of the transmitter is very limited due to its size
3. Missile accuracy is decreased by the additional guidance equipment requirement
4. Each of the above

2-15. Which of the following types of homing guidance depends only on the target as a source of electromagnetic radiations?

1. Active
2. Semiactive
3. Passive
4. Each of the above

2-16. Which of the following is an advantage of passive homing?

1. The missile can be larger
2. The missile cannot be detected by the target
3. The missile doesn't need as much speed
4. The missile uses a smaller illuminator

Learning Objective: Describe various missile flight paths and how they are used by SMS missiles.

2-17. Which of the following factors that affect the missile's flight path can be controlled?

1. Steering only
2. Steering and wind
3. Gravity and steering
4. Gravity and wind

2-18. Which of the following types of flight paths is used by the Harpoon missile?

1. Constant preset
2. Complex preset
3. Complex programmed
4. Programmed preset

2-19. What types of flight paths do (a) homing missiles and (b) beam-rider missiles use?

1. (a) Pursuit (b) collision
2. (a) Collision (b) line-of-sight
3. (a) Pursuit (b) collision
4. (a) Line-of-sight (b) pursuit

2-20. Which of the following is/are characteristic of the pursuit curve?

1. At any instant the course of the missile is toward the target
2. A missile pursuing a crossing target flies a curved trajectory
3. Both 1 and 2 above are characteristic
4. A missile will first climb to altitude, then dive on the target

2-21. In which of the following ways does a homing missile that flies a collision course intercept a target?

1. By trying to maintain successive lines of sight parallel
2. By using sensor units to point the missile directly at the target
3. By calculating the speed of the target
4. By flying a curved flight path to the collision point

2-22. A collision course offers which of the following advantages over a pursuit course?

1. Missile course curvature is decreased
2. Missile course curvature is increased
3. Greater fuel economy is offered
4. Greater range is offered

2-23. Proportional navigation means that the missile turns at a rate that is proportional to

1. missile speed
2. target speed
3. rate of change of the line of sight
4. rate of change of the missile speed

2-24. The beam-rider missile follows what kind of path?

1. Line-of-sight
2. Pursuit
3. Collision
4. Proportional navigation

2-25. The beam-rider path is similar to what kind of path?

1. Line-of-sight
2. Pursuit
3. Collision
4. Proportional navigation

Learning Objective: Classify the SMS missiles according to their characteristics.

2-26. The TARTAR missile was replaced by which of the following missiles?

1. RIM-24C
2. RIM-66A
3. RIM-66B
4. Both 2 and 3 above

2-27. The STANDARD RIM-66D missile has which of the following characteristics?

1. It is a beam-rider
2. It uses a booster
3. It uses active homing
4. It homes on enemy radars

2-28. The TERRIER missiles compare to TARTAR missiles in which of the following ways?

1. Terriers use boosters while TARTAR missiles do not
2. Both TERRIER and TARTAR missiles carry nuclear warheads
3. Both TERRIER and TARTAR missiles use homing guidance
4. Each of the above ways

2-29. Which of the following SMS missiles was originally designed for air launch?

1. TARTAR
2. TERRIER
3. SPARROW III
4. STANDARD (ER)

IN ANSWERING QUESTIONS 2-30 THROUGH 2-34, SELECT FROM COLUMN B THE TYPE OF GUIDANCE THAT APPLIES TO THE MISSILE LISTED IN COLUMN A.

A. MISSILE	B. GUIDANCE
2-30. STANDARD ARM	1. Terrain matching
	2. Trajectory shaping
2-31. STANDARD SM2	3. Passive homing
	4. Active homing
2-32. HARPOON	
2-33. TOMAHAWK L-A	
2-34. RAM	

Learning Objective: Explain the basic elements of the fire control problem.

2-35. An accurate solution of the fire control problem would result in which of the following?

1. A successful missile launch
2. Effective control of the missile
3. Accurate target position data
4. A minimum of fire damage

2-36. The invisible line from the fire control radar to the target is called the line of

1. sight
2. view
3. fire
4. launch

2-37. The imaginary line along which the missile is fired is called the

1. sight angle
2. launch angle
3. line of fire
4. line of launch

2-38. The search radar provides target detection under which of the following conditions?

1. At short distances only, during darkness, and in all types of weather
2. At long distances, during the day only, and in all types of weather
3. At long distances, during the day only, and in clear weather only
4. At long distances, day or night, and in all types of weather

2-39. Initial target position is usually provided by which of the following?

1. Fire control radar
2. Search radar
3. Fire control computer
4. Missile guidance computer

2-40. All of the following information, transmitted to the fire control computer, is ancillary data with the exception of

1. target speed
2. wind velocity
3. own ship course
4. stabilization correction

2-41. What subsystem of the fire control system provides all necessary data on the target?

1. Computer
2. Launcher
3. Tracking radar
4. Guidance transmitter

2-42. What weapon subsystem calculates the launcher line of fire?

1. Computer
2. Launcher
3. Tracking radar
4. Guidance transmitter

2-43. Which of the following methods is used to reposition the command guided missile during its flight?

1. Guidance beam
2. Computer orders
3. Tracking radar beam
4. Radar reflections from the target

2-44. Why must the missile seeker antenna slew to look for the target?

1. The target is faster than the missile
2. The missile is faster than the target
3. The target is not flying directly toward the ship
4. The missile is not fired directly toward the target

2-45. Which of the following miss-producing effects is NOT compensated for?

1. Gravity
2. Wind
3. Air resistance
4. Ship movement

Learning Objective: Identify the various reference frames and symbols used in describing the fire control problem.

2-46. Fire control symbols have elements that represent which of the following information?

1. Main class and where it is measured
2. Main class and how it is measured
3. Distance and how it is measured
4. Distance and where it is measured

2-47. What are the differences in meaning, if any, between basic symbol "M", symbol modifier "m", and quantity modifier "m"?

1. Basic symbol "M" is linear movement, symbol modifier "m" is missile, and quantity modifier "m" is relative motion
2. Basic symbol "M" is missile, symbol modifier "m" is linear movement, and quantity modifier "m" is relative motion
3. Basic symbol "M" is relative motion, symbol modifier "m" is linear movement, and quantity modifier "m" is missile
4. None; they all mean the same

2-48. If Rhx is east-west horizontal range, what is Rhx2?

1. Twice the horizontal range
2. Horizontal east-west advance range
3. Horizontal east-west aiming range
4. Horizontal east-west future range

2-49. Launcher bearing order in the deck plane is represented by what symbol?

1. LBod
2. Bdgl
3. Bgdo
4. gBod

2-50. Quantity modifiers are identified by which of the following?

1. Parentheses
2. x and y
3. 1 through 6
4. QM

2-51. A symbol that precedes a parenthesis sign defines which of the following?

1. A correction to a quantity
2. How a quantity is obtained
3. A corrected quantity
4. Both 1 and 2 above

2-52. What factors are necessary to describe the position of a target?

1. Distance, direction, and speed
2. Distance, speed, and reference point
3. Direction, distance, and reference point
4. Direction, speed, and reference point

2-53. Systems of measurement from a known reference point are referred to as

1. reference systems
2. coordinate systems
3. measuring systems
4. positioning systems

2-54. The reference points that are used in missile fire control are normally located in what place(s)?

1. Missile only
2. Ownship only
3. Missile and ownship only
4. Missile, ownship, and target

2-55. The frame of reference RIGIDLY ATTACHED TO OWNSHIP has its reference point located in what plane?

1. Deck plane
2. Ownship plane
3. Earth plane
4. Horizontal plane

2-56 The horizontal plane is established by a

______(a)______ and is
(gyroscope), (director)
______(b)______ ship's
(dependent on), (independent of)
roll and pitch.

1. (a) director (b) independent of
2. (a) director (b) dependent on
3. (a) gyroscope (b) dependent on
4. (a) gyroscope (b) independent of

2-57. In a partially stabilized system, launcher quantities are measured in what planes?

1. Deck and vertical
2. Deck and normal
3. Horizontal and normal
4. Horizontal and vertical

Learning Objective: Point out and describe the coordinate systems used in missile fire control.

2-58. Locating a point in a plane requires what total number of coordinates?

1. One
2. Two
3. Three
4. Four

2-59. The two basic coordinate systems are known as

1. cartesian and rectangular
2. rectangular and angular
3. polar and rectangular
4. angular and cartesian

2-60. Which of the following choices describes the location of a point in a rectangular coordinate system labeled (6,-2)?

1. Six units to the right of the origin along the X axis and two units above the origin along the Y axis
2. Six units to the left of the origin along the X axis and two units above the origin along the Y axis
3. Six units to the right of the origin along the X axis and two units below the origin along the Y axis
4. Six units to the left of the origin along the X axis and two units below the origin along the Y axis

2-61. In what quadrant of a rectangular coordinate system is a point if the coordinates of the point are (-3, 4)?

1. First quadrant
2. Second quadrant
3. Third quadrant
4. Fourth quadrant

2-62. What quantities, used to express target position, do the polar coordinates (6, 20°) describe?

1. Altitude and elevation angle
2. Range and elevation angle
3. Range and bearing angle
4. Altitude and bearing angle

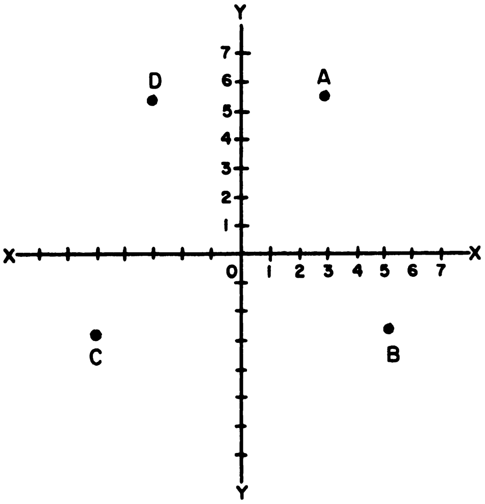

Figure 2A. Polar coordinates.

IN ANSWERING QUESTION 2-63, REFER TO FIGURE 2A.

2-63. If a point in a fire control polar coordinate system has the coordinates (6, 120°), the point is located at point

1. A
2. B
3. C
4. D

2-64. Deviation of a point from a reference plane can be described by which of the following means?

1. Angular and linear values
2. Velocity
3. X and Y quantities
4. Each of the above

2-65. The polar coordinate Rh is ______(a)______ the reference
(in), (perpendicular to)
plane and coordinate E is measured ____________ the reference plane.
(from), (in)

1.	(a) in	(b) in
2.	(a) perpendicular to	(b) in
3.	(a) perpendicular to	(b) from
4.	(a) in	(b) from

2-66. In what axis of a three-dimensional coordinate system do we measure altitude?

1. Rh
2. X
3. Y
4. Z

2-67. For which of the following reasons is coordinate conversion necessary?

1. Fire control radars use two coordinate systems
2. Search radars use two coordinate systems
3. Weapon system elements use different coordinate systems
4. Weapon system elements use similar coordinate systems

IN ANSWERING QUESTION 2-68 REFER TO TEXTBOOK FIGURE 3-13 ON PAGE 3-13

2-68. With respect to origin 0, assume that the coordinates of point P in a coordinate system are (-4, 2), and the coordinates of a reference origin 0' of a translated axis are (-3, -6). What are the coordinates of point P with respect to origin 0' of the translated axis?

1. (-1, -4)
2. (-1, 8)
3. (-7, -4)
4. (7, -8)

2-69. Which of the following fire control coordinate systems use(s) the slant plane between own ship and the target as one of the coordinates describing target position?

1. Cylindrical
2. Cartesian
3. Spherical
4. All of the above systems

IN QUESTIONS 2-70 THROUGH 2-72, SELECT FROM COLUMN B THE COORDINATES THAT ARE USED IN THE COORDINATE SYSTEMS LISTED IN COLUMN A.

	A. COORDINATE SYSTEM	B. COORDINATES
2-70.	Spherical	1. Three angular
		2. Three linear
2-71.	Cylindrical	3. One linear and two angular
2-72.	Cartesian	4. One angular and two linear

2-73. The plan position indicator (PPI) of a radar permits simultaneous indications of

1. bearing and altitude
2. bearing and elevation
3. true bearing and slant range
4. elevation and range

Assignment 3

The Fire Control Problem, Missile Controls, and System Maintenance

Textbook Assignment: FTM 3, NAVEDTRA 10224; pages 3-15 through 4-4

3-1. What is used as the reference for antenna position?

1. Ship's centerline
2. True north
3. Ship's heading
4. Relative heading

3-2. A relative bearing of 090° and a ship's heading of 180° results in a true bearing of

1. 090°
2. -090°
3. 180°
4. 270°

3-3. A target's elevation angle can be calculated from which of the following?

1. Rv and R
2. Vertical range and slant range
3. Target height and slant range
4. Each of the above

3-4. Director position quantities Bd' and Ed' are in which of the following coordinates?

1. Spherical polar
2. Spherical rectangular
3. Normal polar
4. Normal rectangular

Learning Objectives: Define the main functions of the weapon control system.

3-5. Coordinate conversion refers to the changing of which of the following types of data?

1. Rectangular to spherical
2. Spherical to cylindrical
3. Deck plane to horizontal
4. Each of the above

3-6. Control of the missile involves the selection of the missile _____a_____ and
(location), (type)
the computation of missile ____b____
__________. (orders),
(position)

3-7. Information required by the weapon control system includes

1. target location, type, and threat
2. target type and threat only
3. target threat only
4. target location only

Learning Objective: Explain the roles of the various equipments used in target detection.

3-8. Which of the following actions is NOT considered to be data gathering?

1. Target tracking
2. Launcher positioning
3. Target detection
4. Ancillary data collection

3-9. Which of the following equipment is NOT used for target detection?

1. Error detectors
2. Optical devices
3. Fire control radars
4. ESM

3-10. What is the primary source of air target information for the weapon system during the detection operation?

1. NTDS
2. Navigation radar
3. Two-coordinate radars
4. Three-coordinate radars

3-11. The principal advantage of two-coordinate radars is

1. long range detection
2. elevation information
3. identify-friend-or-foe
4. electronic counter-counter-measures

3-12. Which of the following radars is especially useful in detecting low flying enemy targets?

1. AN/SPS-40
2. AN/SPS-48
3. AN/SPS-55
4. AN/SPS-60

3-13. ESM equipment is used to detect a target's

1. rf radiation
2. sound waves
3. heat radiation
4. movement

3-14. Outputs from the ESM system are often used to trigger which of the following equipment?

1. Search radar
2. ECM
3. Fire Control radar
4. ECCM

3-15. Which of the following input data supports own-ship data inputs to NTDS?

1. Aircraft
2. Other ships
3. Shore stations
4. All of the above

IN ANSWERING QUESTIONS 3-16 THROUGH 3-20 SELECT FROM COLUMN B THE EQUIPMENT THAT PROVIDES THE FUNCTION LISTED IN COLUMN A.

	A. FUNCTION	B. EQUIPMENT
3-16.	Fire missiles	1. NTDS
		2. WDS
3-17.	Correlate tactical data	3. WDS ancillary
3-18.	Select missiles	
3-19.	Assign targets	
3-20.	Indicate tracking status	

Learning Objective: Recognize the functions performed by the fire control director/radar during tracking.

3-21. The primary function of the operator in the radar control room of a missile ship is to

1. make repairs to the equipment
2. search for and track targets
3. monitor the operation of the equipment
4. control the operation of the equipment

3-22. Where do the target designation signals which position the director/radar set at the correct range, bearing, and elevation normally originate?

1. In the fire control switchboard
2. In the fire control computer
3. In the optical target designation transmitter
4. In the weapons direction equipment

3-23. Designations between fire control systems are called

1. interdirector designations
2. intermediate designations
3. interrelated directors
4. interconnected directors

3-24. A semiactive homing missile will lock onto what type of radar signal?

1. The transmitted tracking beam
2. The reflected tracking beam
3. The transmitted illumination beam
4. The reflected illumination beam

3-25. In the missile control problem, the effect of the ship's roll and pitch on the fire control radar is compensated for by gyros located in the

1. radar control room below decks
2. ship's gyro room
3. radar antenna housing unit
4. missile launcher assembly

QUESTIONS 3-26 THROUGH 3-28 ARE TO BE JUDGED TRUE OR FALSE.

3-26. In the absence of a gyro-order signal, a gyroscope preserves a direction that remains fixed in space during the occurrence of motion.

3-27. Gyro precession causes the antenna drive mechanism to move the antenna at the same rate and direction of the ship's roll during tracking operations.

3-28. During target tracking, the gyro torque motor will reposition the gyro with respect to space, while at the same time move the antenna to follow the target.

Learning Objective: List the desired characteristics of computing subsystems in relation to types of computers and typical computations.

3-29. Which of the following data is NOT generated by the fire control computer?

1. Launcher orders
2. Repeat-back data
3. Designation data
4. Lead angle

3-30. Repeat-back data is used for which of the following purposes?

1. To close the tracking loop
2. To act as a secondary solution
3. To position the radar/director
4. To update WDS displays

3-31. Which of the following is one of the primary functions of the guided missile fire control computer?

1. Establish missile range
2. Determine target location
3. Convert target data to useful forms
4. Provide a guidance beam to the missile

3-32. With respect to the two basic types of computers, how do the (a) digital and (b) analog computers calculate?

1. (a) Measures, (b) tracks
2. (a) Tracks, (b) records
3. (a) Records, (b) counts
4. (a) Counts, (b) measures

3-33. The foundation of analog computation is the creation of a scale factor between the data and the

1. defined numbers
2. discrete signals
3. electronic pulses
4. computing mechanism

3-34. Which of the following makes an analog computer adaptable to fire control antiaircraft problems?

1. Problem switching capabilities
2. Continuous measurements
3. Unlimited precision
4. All of the above

3-35. A digital computer uses what kind of data to solve problems?

1. Numerical equivalents
2. Rotational equivalents
3. Shaft rotation
4. Shaft increments

3-36. The value of the least significant bit of a digital computer register determines the

1. capacity of input
2. speed of computation
3. capability of switching
4. limitation of precision

3-37. The fire control computer requires inputs in which of the following basic forms to perform its functions?

1. Digital and analog data
2. Positive and negative logic
3. Data and control signals
4. Status and control signals

3-38. What are the three major modes of operation of the GMFCS?

1. Air ready, designate, and track
2. Designate, track, and launch
3. Air ready, track, and launch
4. Air ready, designate, and launch

3-39. The term "air ready" means the system is ready for

1. air targets
2. designation
3. tracking
4. missile launch

3-40. The fire control director is positioned by which of the following equipment in the designation mode?

1. NTDS
2. WDS
3. Fire control computer
4. Fire control radar

3-41. Which of the following conversion processes is performed by the computer in a closed tracking loop?

1. Tracking rates to tracking errors
2. Tracking errors to computing errors
3. Tracking rates to computing rates
4. Tracking errors to tracking rates

3-42. Which of the following characteristics apply to the geometric coordinates used in the computer for solving the fire control problem?

1. Converted
2. Stable
3. Unconverted
4. Unstable

Learning Objective: Describe the launching and guidance control of the missile.

3-43. The fire control computer calculates the launcher positioning orders so that when launched, the

1. homing missile acquires and locks on the target
2. beam-riding missile acquires and locks on the target
3. homing missile intercepts the guidance beam
4. beam-riding missile follows a pursuit flight path

3-44. Missile launcher load position is generally determined by which of the following?

1. Missile type selection
2. Missile orders
3. Magazine type
4. Ship class

3-45. Launcher orders may consist of which of the following?

1. Missile rates, type, and number
2. Missile mode, number, and launcher position
3. Missile rates, type, and launcher position
4. Missile type and number only

QUESTIONS 3-46 THROUGH 3-49 ARE TO BE JUDGED TRUE OR FALSE.

3-46. The type of homing employed by a guided missile depends on the source of the rf energy detected by the tracking radar on the launching ship.

3-47. The fire control system of the launching ship may engage another target as soon as active homing guidance is initiated.

3-48. During semi-active homing, the launching ship cannot break off the target once the missile is launched.

3-49. In the passive homing guidance system, the launching ship must continuously participate in the engagement until intercept occurs.

3-50. In what type of guidance system are the control signals computed aboard ship and sent to the missile by a data link?

1. Beam rider
2. Active
3. Command
4. Semiactive

3-51. Missile orders are applied to the missile at which of the following times?

1. After launch
2. At launch
3. Before launch
4. All of the above

3-52. Missile roll order is used for which of the following purposes?

1. To cause the missile to roll throughout its flight
2. To keep the missile from rolling during flight
3. To keep the missile vertical during launch
4. To return the missile to vertical after launch

3-53. Head aim orders are needed on
________a________ missiles
(homing), (beam rider)
because they are fired directly
at a ________b________.
(target), (collision point)

1. (a) Homing (b) target
2. (a) Beam rider (b) target
3. (a) Homing (b) collision point
4. (a) Beam rider (b) collision point

3-54. Missile steering gain is also known as which of the following?

1. Seeker head rate
2. Tail control rate
3. Navigation ratio
4. Variable navigation ratio

3-55. The missile is allowed to ascend to high altitudes by the use of VNR and

1. high steering gain
2. constant navigation ratio
3. director offset
4. superelevation

3-56. The missile climbing to higher altitudes results in which of the following?

1. More aerodynamic drag
2. More maneuverability
3. Loss of boost velocity
4. Greater initial velocity

3-57. The Doppler predict signal represents a predicted value of

1. missile-to-target range rate
2. target speed
3. illuminator frequency
4. reflected signal frequency

Learning Objective: Define the basic processes which occur in a weapon control system.

3-58. Which of the following methods may be used to identify a target as friendly?

1. Visual identification
2. Verbal communication
3. IFF transmission
4. Each of the above

3-59. All of the following counter-countermeasures are effective in defeating jamming techniques with the exception of

1. missile homing devices
2. radar receiver delay circuits
3. trained efficient radar operator
4. stable pulse repetition frequency

3-60. Launcher positioning orders must be within a specified tolerance when launching a guided missile due to the limitation of

1. elapse time between launcher loading and firing
2. missile velocity during the boost phase of flight
3. gain control within the missile's guidance system
4. target range data obtained from the tracking radar

3-61 What function does the (a) attitude control system and (b) flight path control system perform in the missile's guidance system?

1. (a) Reduces flight deviations from the ordered flight path, (b) Resolves the target intercept trajectory
2. (a) Determines the prelaunch ballistic error correction, (b) Compensates for roll, pitch, and yaw motion
3. (a) Resolves the target intercept trajectory, (b) Reduces flight deviations from the ordered flight path
4. (a) Compensates for roll, pitch, and yaw motion, (b) Determines the prelaunch ballistic error correction

3-62. Positioning the tracking radar to the approximate position of the target occurs during

1. detection
2. designation
3. acquisition
4. prediction

Learning Objective: Explain the basic purpose of the 3-M systems and their relationship to weapon system testing.

3-63. The Navy's total approach to maintenance is called the

1. Planned Maintenance System
2. Maintenance Data System
3. Ship's Maintenance and Material Management Systems
4. Navy Maintenance Plan

3-64. What are the principal parts of the 3-M systems?

1. PMS and MDS
2. PMS and CMS
3. CMS and MDS
4. CMS and PMD

3-65. Which of the following documentation provide for effective management of SMS maintenance?

1. Systems OPs/TMs
2. Equipment OPs/TMs
3. PMS manual
4. All of the above

3-66. Which of the following is a purpose of PMS documentation?

1. To enable personnel to perform testing and servicing in the maximum time allowed
2. To enable personnel to rapidly diagnose faults through logical testing
3. To allow personnel a means of reporting equipment failures
4. To allow personnel a ready means of documenting equipment failures

3-67. Which of the following are maintenance tools provided by PMS?

1. Lint-free rags
2. Lubricating charts
3. Multimeters
4. MRCs

3-68. Which of the following provide a list of MRCs, frequency of performance, and required skill levels for equipment maintenance?

1. MIPs
2. System OPs/TMs
3. Equipment OPs/TMs
4. Each of the above

3-69. In what document are the MIPs located?

1. Technical manual
2. PMS manual
3. Equipment OP
4. Cycle schedule

3-70. What document lists the scheduled maintenance requirements to be performed between major overhauls?

1. Technical manual
2. PMS manual
3. Equipment OP
4. Cycle Schedule

3-71. Which of the following should be referred to for daily work assignments?

1. Technical manual
2. Equipment OP
3. Weekly schedule
4. Daily schedule

3-72. Which of the following are NOT provided by MRCs?

1. Standardized maintenance procedures
2. Data concerning the nature of malfunctions
3. Lists of tools needed for maintenance
4. Safety precautions to be followed

Learning Objective: Describe in basic terms the purpose and characteristics of system testing.

3-73. How often are system tests scheduled to ensure reliable system performance?

1. As often as necessary
2. Daily when the ship is in port
3. Daily when the ship is at sea
4. Whenever the system is inoperable

3-74. System tests are designed to check which of the following?

1. Various operational modes
2. Alignment between parts of an equipment
3. Operation against hostile targets
4. Each of the above

3-75. System test results can NOT be determined by which of the following?

1. Error recorder printouts
2. Digital multimeters
3. Yard sticks
4. Error meters

Assignment 4

System Testing and Safety, and Fire Control Radars

Textbook Assignment: FTM 3, NAVEDTRA 10224, pages 4-4 through 5-6

Learning Objective: Define system and equipment troubleshooting documentation and how it is used.

4-1. Which of the following is known as system level documentation?

1. Indicator Fault Directory
2. Test Fault Directory
3. Fault Logic Diagram
4. Each of the above

IN ANSWERING QUESTIONS 4-2 THROUGH 4-5, REFER TO FIGURE 4-3, PAGE 4-5, IN THE TEXT AND SELECT FROM COLUMN B THE DOCUMENTATION APPROPRIATE FOR THE INDICATION OF FAILURE LISTED IN COLUMN A.

	A. FAILURE	B. DOCUMENTATION
4-2.	Equipment Operation	1. Fault Logic Diagrams
4-3.	System operation	2. Signal Flow Diagrams
4-4.	System test	3. Troubleshooting Index
4-5.	Equipment test	

4-6. System documentation (a) ________________ throughout the fleet and troubleshooting techniques (b) ________________ between systems.

1. (a) Does not vary (b) vary
2. (a) Does not vary (b) do not vary
3. (a) Varies (b) do not vary
4. (a) Varies (b) vary

IN ANSWERING QUESTIONS 4-7 THROUGH 4-10, SELECT THE CORRECT DOCUMENT FROM THOSE LISTED BELOW.

A. Fault Logic Diagram
B. System Functional Diagram
C. Indicator Fault Directory
D. Troubleshooting Index

4-7. Which document is in alphabetical order, and references the pertinent System Functional Diagram?

1. A
2. B
3. C
4. D

4-8. Which document uses external indications to answer a "yes" or "no" series of branching questions?

1. A
2. B
3. C
4. D

4-9. Which system troubleshooting tool serves as a flow diagram for system analysis?

1. A
2. B
3. C
4. D

4-10. A list of all equipment output functions and applicable functions can be found in

1. A
2. B
3. C
4. D

Learning Objective: Explain in basic terms weapon system testing requirements, coverage, and procedures.

4-11. The normal mode of surface missile system operation is known as

1. surface mode
2. antiair mode
3. antiship mode
4. shore mode

4-12. What are the two major requirements necessary to ensure reliable system performance?

1. Proper alignment and testing
2. Proper alignment and operation
3. Maintenance and testing
4. Testing and operation

4-13. What is the time requirement for scheduling rf and internal alignments?

1. Quarterly
2. Annually
3. Biannually
4. Only as required

4-14. The daily system operability test has a periodicity code of

1. D only
2. DSOT
3. D or W
4. W only

4-15. Which of the following would NOT be a missile system test?

1. Balloon tracking test
2. Search radar readiness test
3. Gunfire support test
4. Ship parameters test

4-16. Which of the following is NOT a characteristic of system tests?

1. The test conductor can control the test while monitoring system status
2. Each station requires a test conductor
3. Many stations can participate simultaneously
4. One person can record all necessary data

4-17. What characteristic of a system test allows part of a system to be checked without conducting an entire test?

1. The step-by-step format
2. The test procedure response column
3. The recorded data
4. The independent test phases

4-18. Error evaluation is accomplished by comparing the tested parameters with

1. specific responses and tolerances
2. previous responses and errors
3. fault isolation directories
4. indicator fault directories

4-19. If an undesired response is observed, the test conductor should take which of the following actions?

1. Find the cause before proceeding with the test
2. Isolate the problem to a particular equipment and postpone the test
3. Complete the test, if possible, before attempting to isolate the problem
4. Correct the problem, then proceed with the test

4-20. In a digital system, the fire control problem is solved by a

1. fire control radar
2. weapon direction equipment
3. digital data converter
4. digital computer

4-21. In digital systems, what equipment controls the system test?

1. A fire control radar
2. A weapon direction equipment
3. A digital test set
4. A digital computer

4-22. The digital test program compares actual tracking solutions with what to provide error monitoring?

1. Pre-loaded data
2. Print-out data
3. Computed ideal values
4. Computed average values

Learning Objective: Indicate the purpose of the Daily System Operability Test and the various functions tested.

4-23. What is the primary reason for conducting daily system operability tests?

1. To isolate equipment faults
2. To localize interface problems
3. To perform system alignment maintenance
4. To assess weapon control system readiness

4-24. The preliminary set up for system tests usually includes which of the following procedures?

1. Switch positioning
2. Equipment turn-on
3. Both 1 and 2 above
4. Configuration selection

4-25. Designation accuracy is checked at which of the following stations?

1. Fire control radar
2. FCS assignment console
3. WDS
4. NTDS/WDS

4-26. Fire control radar acquisition is monitored at what station?

1. Radar console
2. Director dials
3. WDS
4. Analog test set

4-27. Which of the following procedures is NOT performed during DSOT?

1. Selection of missile mode
2. Verification of a live missile
3. Acquisition during jamming
4. Launcher assignment

4-28. To verify the fire control problem solution, what information is/are monitored?

1. Launcher and missile orders
2. Radar tracking errors
3. Test meter readings
4. Computer dial settings

4-29. Simulated missile-in-flight indications can be observed at which of the following stations?

1. Launcher
2. Computer
3. NTDS/WDS
4. Each of the above

4-30. Before you approach a missile on the launcher, what should be secured?

1. The computer
2. The director
3. The launcher motors
4. The switchboard

4-31. The OCSOT tests which systems and/or equipment?

1. Missile systems only
2. Gun and missile systems only
3. Any combat related equipment
4. All electronic equipment

Learning Objective: Explain in general terms the theory of weapon system alignment.

4-32. What type of reference is used to accomplish the alignment of all elements of a weapon system?

1. Common
2. Mechanical
3. Electrical
4. Line-of-sight

4-33. Who is/are responsible for initial internal alignment of a weapon system element?

1. The shipyard
2. The manufacturer
3. Shipboard personnel
4. Techreps

4-34. When all system elements have parallel lines of sight and dials that all agree, the system is said to be aligned in what manner?

1. Internally
2. Mechanically
3. Marginally
4. Critically

4-35. Benchmark data is used to verify what type of alignment?

1. Internal
2. External
3. Mechanical
4. Optical

4-36. What reference plane is used for the machining of the reference element foundation?

1. Horizontal plane
2. Deck plane
3. Roller path plane
4. Construction base plane

4-37. Which of the following weapon system elements is/are aligned to the fire control reference plane?

1. Fire control directors only
2. Fire control reference element
3. Launchers and gun mounts only
4. All major elements

4-38. Where is the zero train reference plane for all weapon system elements located?

1. Perpendicular to the fire control reference plane, lying along the ship's centerline
2. Perpendicular to the deck plane, parallel to the ship's centerline
3. Parallel to the vertical plane, lying along the fire control reference plane
4. Parallel to the fire control reference plane, perpendicular to the ship's centerline

4-39. Ship's force is primarily responsible for which of the following types of alignment?

1. Afloat
2. Drydock
3. Initial
4. Periodical

Learning Objective: Identify safety precautions applicable to missile system testing.

4-40. In your development in the fields of KNOWLEDGE, SKILLS, and SAFETY, which field should be given prime importance?

1. KNOWLEDGE
2. SKILLS
3. SAFETY
4. All three are equally important

4-41. Which of the following is a safety philosophy that is fundamental to recognizing unsafe conditions?

1. Being able to predict unexpected occurrences
2. Awareness of every possible unsafe situation
3. Understanding the basic ideas behind safety precautions
4. Observance of special safety precautions set forth in local directives

4-42. When you perform a step-by-step procedure, such as in missile handling or testing, safety can best be maintained during the sequence by ensuring

1. that operations are carried out slowly and methodically
2. familiarity with your assigned duties
3. correct results from the preceding step
4. proper indications of malfunction

4-43. Which of the following statements is NOT correct concerning safety devices?

1. They must be kept in good order at all times
2. Bypass them only during DSOT
3. Do not remove them without authorization
4. If inoperative, post a warning notice

4-44. Rf energy can enter a weapon through which of the following?

1. Hole or crack
2. Insulated seams
3. Wet surfaces
4. Metal surfaces

4-45. Possible effects of premature actuation of an electroexplosive device include(s) which of the following?

1. Warhead detonation
2. Propellant dudding
3. Propellant ignition
4. All of the above

4-46. One of the purposes of the precautions associated with operating fire control equipment is to protect

1. only those men working on hazardous equipment
2. only those men working under hazardous conditions and those in the immediate vicinity
3. only those men in the immediate vicinity of a hazardous operation
4. any personnel who might be endangered by hazardous equipment or conditions

4-47. A periodical review of safety precautions would be most likely to improve tasks that are performed at which of the following times?

1. Rarely
2. Routinely
3. Frequently
4. Instinctively

Learning Objective: Define principles of radar and compare fire control with search radars.

4-48. What are shipboard radars used to detect?

1. Enemy aircraft only
2. Enemy surface targets only
3. Enemy and friendly aircraft only
4. Enemy and friendly craft and missiles

4-49. A radar will detect which of the following objects?

1. Any unobstructed object in the beam's path
2. Any object within the transmitter's range
3. Any unobstructed object within range and in the beam's path
4. Any object that reflects radiowaves

4-50. The reflected pulse is detected by the

1. antenna
2. receiver
3. indicator
4. transmitter

4-51. The distance of the reflecting object is obtained by

1. measuring transmission time
2. measuring elapsed time between pulse transmission and reception of echo
3. measuring the size of the echo
4. counting the pulses between echos

4-52. Search radars have which of the following characteristics?

1. Relatively broad beams
2. Continuous rotation through 360°
3. Relatively high beams
4. Each of the above

4-53. In comparison to a search radar, a fire control radar has which of the following characteristics?

1. Wider beam
2. Longer scan time
3. Greater scan area
4. Greater accuracy

4-54. The feature that allows search radars to track targets is known as

1. automatic detection and tracking
2. automatic target discrimination
3. target track mode
4. target processing mode

4-55. The ability of a radar to distinguish between two close targets is known as

1. refraction
2. resolution
3. discrimination
4. diffraction

Learning Objective: Specify basic types of radar energy transmissions.

4-56. What are the two basic types of energy transmission in radars?

1. Pulse and Doppler
2. Pulse and short wave
3. Pulse and CW
4. Doppler and CW

4-57. If the reflected signal is the same frequency as the transmitted signal, which of the following facts is known about the target?

1. It is stationary
2. It is very slow
3. It is a ship
4. It is a plane

4-58. Pulse repetition time may be defined as the

1. reciprocal of pulse width
2. pulse repetition frequency subtracted from the digit one
3. period of time required for the pulse to travel to the target and return to the source
4. period of time from the beginning of one transmitted pulse to the beginning of the next

4-59. Which of the following statements is true concerning peak power and average power of a pulse type radar set?

1. Average power expended is always greater than peak power.
2. Average power should approximate peak power to obtain maximum range.
3. Peak power is the power expended during the transmission of a pulse, and average power is the power expended over the pulse repetition period.
4. Average power is the power expended during the transmission of a pulse, and peak power is the power expended over the pulse repetition period.

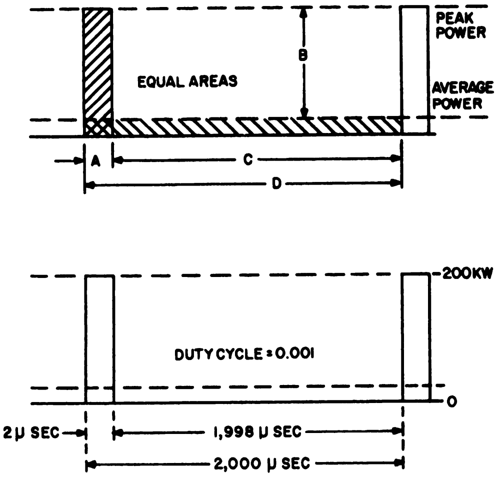

Figure 4A. Relationship of peak and average power and duty cycle.

REFER TO FIGURE 4A IN ANSWERING QUESTIONS 4-60 THROUGH 4-62.

4-60. What determines the minimum range at which a target can be detected?

1. A
2. B
3. C
4. D

4-61. What may be increased in order to decrease the average power level?

1. A
2. B
3. C
4. All of the above

4-62. What is the average power?

1. 0.02 kW
2. 0.20 kW
3. 2.00 kW
4. 20.00 kW

4-63. When electromagnetic waves are reflected off a target, how, if at all, is their velocity changed?

1. It is increased an amount equal to target speed
2. It is decreased an amount equal to target speed
3. It doubles
4. It does not change

4-64. In what total time does an rf wave travel one nautical mile?

1. 3.05 μs
2. 6.1 μs
3. 12.2 μs
4. 24.4 μs

4-65. What is the time required for two-way travel of an rf pulse if the target is 65,600 yards from the radar?

1. 200 μs
2. 300 μs
3. 400 μs
4. 500 μs

4-66. Which one of the following statements is true concerning Doppler effect?

1. The Doppler frequency is too small at radar frequencies to be usable until it is multiplied to a higher frequency.
2. The transmitted signal's frequency increases when the relative range is closing and decreases when the relative range is opening.
3. The magnitude of frequency shift is inversely proportional to the relative range.
4. The magnitude of frequency shift is small when the relative range is opening and large when the relative range is closing.

4-67. The Doppler frequency, caused by the Doppler effect, is a measure of the target's

1. size
2. height
3. velocity
4. range

4-68. Frequency modulated radars transmit a wave that is continuously changing in frequency about a center frequency. Using frequency modulation, the range to a target is determined by

1. comparing the frequency of the signal that is presently being transmitted with the received frequency that has been reflected from the target
2. comparing the magnitude of pulses that have been transmitted at one frequency with the magnitude of reflected pulses at a second frequency
3. measuring the velocity of the received energy and comparing it with the velocity of the energy being transmitted
4. measuring the Doppler shift that has occurred in the returning signal

4-69. What characteristics of a reflected pulse are affected by the Doppler shift?

1. Amplitude and polarity
2. Amplitude and frequency
3. Pulse width and polarity
4. Pulse width and frequency

4-70. The beat signals produced by the reference oscillator and moving target echo signals in a pulse Doppler radar are

1. displayed on the radar scope
2. canceled out in the radar receiver
3. subtracted from the Doppler frequency
4. locked in phase with the transmitted pulse

4-71. A pulse Doppler radar measures (a) range and (b) velocity in the same way as what types of radar?

1. (a) Cw (b) pulse
2. (a) Pulse (b) pulse
3. (a) Pulse (b) cw
4. (a) Cw (b) cw

Assignment 5

Fire Control Radars and Support Systems

Textbook Assignment: FTM 3, NAVEDTRA 10224; pages 5-6 through 6-7

Learning Objective: Describe radar energy transmission in terms of beam shape, power, and reflection.

5-1. Where is the density of the transmitted rf energy normally measured in fire control radars?

1. At the extremities of the beam
2. At the null points of the wavefront
3. Midway between the wavefront extremities
4. Between the half-power points of the beam width

5-2. The radiated rf beam from a fire control radar should possess which of the following characteristic shapes in order to determine accurate bearing angles to the target?

1. Wide
2. Square
3. Narrow
4. Trapezoidal

5-3. What determines a pulse radar's resolution in (a) range and (b) bearing and elevation?

1. (a) Pulse width (b) beam width
2. (a) Peak power (b) beam width
3. (a) Peak power (b) antenna speed
4. (a) Doppler shift (b) antenna speed

5-4. The intensity of a reflected pulse is dependent on which of the following characteristics of the target?

1. Size and speed
2. Size and shape
3. Direction and shape
4. Direction and speed

5-5. Uneven surfaces reflect in many directions at once. What is this type of reflection known as?

1. Refraction
2. Diffraction
3. Diffusion
4. Dillusion

Learning Objective: Point out the directional features of different radar antennas.

5-6. In describing light waves and radio waves, which of the following statements is NOT correct?

1. They travel at the same speed
2. They have the same frequency
3. They spread in all directions
4. They spread in a spherical pattern

5-7. Which of the following actions permit(s) a parabolic reflector to produce a narrow rf beam?

1. Spherical wavefronts from the antenna are changed to plane wavefronts by the reflector
2. Energy from the feedhorn is concentrated into a circular beam by the reflector
3. Striking and reflecting rays make equal angles with the reflector
4. All of the above actions

5-8. Which of the following characteristics makes a horn radiator a good antenna device?

1. Matched impedance
2. Small mouth area
3. Coaxial output
4. Flexibility

5-9. Feedhorn shadows can be eliminated by

1. making the horn smaller
2. making the reflector smaller
3. offsetting the horn from the center of the reflector
4. putting the horn behind the reflector

5-10. Which of the following are types of lens antennas?

1. Optical and electro-optical
2. Conducting and dielectric
3. Flatplane and spherical plane
4. Microwave and plane wave

5-11. The acceleration or conducting type of lens uses a principle also used in

1. waveguides
2. optics
3. feedhorns
4. reflectors

5-12. Which of the following characteristics of a lens antenna is NOT useful?

1. Refracting a diverging beam into a parallel beam
2. Refracting a parallel beam into a converging beam
3. Eliminating spillover radiation and reducing shadows
4. Eliminating sensitivity to frequency and preventing changes in phase propagation

5-13. In a delay lens, the amount of delay is dependent on which of the following characteristics?

1. Thickness
2. Angle of incidence
3. Dielectric constant
4. Angle of reflection

5-14. An array antenna consists of a group of which of the following elements?

1. Slots
2. Dipoles
3. Horns
4. Each of the above

5-15. In an array antenna, what determines the position of the beam?

1. Relative phase between elements
2. Relative amplitude between elements
3. Total amplitude of elements
4. Scan motor

5-16. Why can a radar NOT produce an ideal beam of parallel rays?

1. The point source is larger than the end of the waveguide
2. The reflector is smaller than the wavelength of the radiated energy
3. The radar beam converges into a crossing pattern
4. The side lobes cancel out the main lobe

Learning Objective: Define common scanning methods and their characteristics.

5-17. Mechanical scanning involves moving which of the following parts of the radar?

1. The feedhorn
2. The reflector
3. The antenna
4. Each of the above

5-18. Which of the following radar elements is normally moved in conical scanning?

1. The feedhorn
2. The reflector
3. The array
4. Each of the above

5-19. During proper conical scanning, what, if anything, happens to the polarization of the beam?

1. It shifts 90°
2. It reverses
3. It rotates with the feedhorn
4. It remains the same

5-20. In a conically scanned radar, what information does the angle error detector use to compute the direction and amount of correction for continuous target tracking?

1. Beam position relative to scan axis only
2. Magnitude of received target signal only
3. Beam position relative to scan axis and magnitude of received target signal only
4. Magnitude of received target signal, beam position relative to scan axis, and return signal polarity of the highest and lowest part of the scan pattern

5-21. In a monopulse radar, information on the target is obtained from what total number of (a) pulses and (b) feedhorns?

1. (a) 1 (b) 1
2. (a) 1 (b) 4
3. (a) 4 (b) 1
4. (a) 4 (b) 4

5-22. Which of the following determine(s) the amount of total return energy received by each of the four horns in a monopulse radar?

1. Microwave lens of the antenna system
2. Target position relative to the beam axis
3. Amount of energy being transmitted out of each horn
4. All of the above

5-23. In a monopulse radar, which of the following signals are required in the receiver to determine the target direction from the center of the beam axis?

1. Traverse error only
2. Elevation error only
3. Traverse error and elevation error only
4. Elevation error, traverse error, and range

5-24. In a monopulse radar, the receiver output pulses indicate the position of the target in relation to the beam axis by

1. polarity only
2. phase and frequency
3. amplitude and polarity
4. frequency and amplitude

5-25. Monopulse tracking is NOT affected by which of the following problems?

1. Random reflectivity
2. Whirling scans
3. Multiple returns
4. Zero tracking errors

5-26. In a COSRO scanner, the ________(a)________
(sum), (difference)
signal is ________(b)________ modulated.
(phase), (amplitude)

1. (a) Difference (b) amplitude
2. (a) Difference (b) phase
3. (a) Sum (b) phase
4. (a) Sum (b) amplitude

5-27. With COSRO, the direction of the target from the beam's center is determined from which of the following?

1. Polarity of the error signal
2. Amplitude of the error signal
3. Frequency of the modulation
4. Phase of the modulation

5-28. What phase relationship is needed between elements of an array to cause the beam to be perpendicular to the antenna's surface?

1. 0°
2. 45°
3. 90°
4. Maximum

5-29. Which of the following actions allows an array to be used for target tracking?

1. Using frequency scanning
2. Dividing the array into quadrants
3. Using solid-state phase shifters
4. Tracking the phase between elements

5-30. Range tracking is obtained by the use of which of the following radar features?

1. Designation error detectors
2. Acquisition and track gates
3. Range detectors
4. Designation drivers

Learning Objective: List the characteristics and basic components of general types of radar systems.

QUESTIONS 5-31 THROUGH 5-34 REFER TO THE FOLLOWING ESSENTIAL COMPONENTS OF A FUNDAMENTAL PULSE RADAR.

A. Timer
B. Antenna
C. Receiver
D. Modulator
E. Indicator
F. Transmitter
G. Duplexer

5-31. What component initiates the time base for visual display of radar information?

1. E
2. G
3. A
4. D

5-32. The transmitted pulse is formed by the (a) and the high power pulse is generated in the (b).

1. (a) F (b) D
2. (a) F (b) A
3. (a) A (b) D
4. (a) D (b) F

5-33. What component(s) radiate(s) the rf energy in a highly directional beam and receive(s) returning echo energy?

1. B only
2. F only
3. B and E
4. F and C

5-34. What component eliminates high receiver impedance during the receiving period?

1. A
2. G
3. E
4. D

5-35. A cw Doppler radar has which of the following characteristics?

1. Unstable operation
2. Accurate ranging
3. Good velocity discrimination
4. Poor clutter rejection

5-36. In a basic cw Doppler radar, the reflected signal is mixed with what other signal to obtain f_d?

1. Part of the transmitted signal
2. The detected frequency
3. A sample from the rf source
4. The frequency difference

5-37. A pulsed Doppler radar provides for
____(a)____ velocity discrimina-
(good), (poor)
tion and ________(b)________
(accurate), (unreliable)
range measurement?

1. (a) good (b) accurate
2. (a) good (b) unreliable
3. (a) poor (b) accurate
4. (a) poor (b) unreliable

5-38. A pulsed Doppler radar requires only one of which of the following?

1. One operator
2. One transmitter
3. One receiver
4. One antenna

IN ANSWERING QUESTIONS 5-39 THROUGH 5-43, SELECT FROM COLUMN B THE TYPE OF SCOPE DESCRIBED IN COLUMN A.

A. DESCRIPTION

5-39. Angle errors depicted by a moving dot

5-40. Display similar to a geographical map

5-41. Intensity-modulated fan display

5-42. Precision sweep centered at the track gate

5-43. Provides bearing information

B. SCOPE

1. PPI
2. T&E scope
3. A-scope
4. RHI

Learning Objective: Describe the procedures used in radar collimation, and identify its purpose.

5-44. Radar collimation provides for the testing and alignment of parallelism between the radar beam axis and the

1. shore tower antenna axis
2. shore tower target axis
3. reflector axis of the antenna
4. optical axis of the antenna

5-45. In radar collimation, when maximum rf energy is received in the horn antenna, the optical sight should intersect with the

1. horn antenna
2. horn antenna plus parallax
3. optical target
4. optical target plus parallax

5-46. Which of the following measurements is NOT performed by use of the shore tower?

1. Television camera axis
2. Angle error sensitivity
3. Proper parallax distance
4. Rf to optical collimation

Learning Objective: Identify methods and characteristics of countermeasures and counter-countermeasures.

5-47. An enemy can use information on your radar's carrier frequency to do which of the following?

1. Disguise its own radar
2. Saturate your radar
3. Decrease its echo signals
4. Modulate its frequency

5-48. ECCM circuits in a radar are designed to aid the operator by

1. filtering out abnormal echos
2. amplifying weak echos
3. stretching short echos
4. shortening long echos

IN ANSWERING QUESTIONS 5-49 THROUGH 5-51, SELECT FROM COLUMN B THE ECCM FEATURE THAT BEST MATCHES THE DESCRIPTION IN COLUMN A.

	A. DESCRIPTION	B. ECCM FEATURE
5-49.	Increases gain with range	1. Iagc
		2. Ftc
		3. PAT
5-50.	Longer return signals are attenuated	4. Stc
5-51.	Negative feedback increases for longer signals	

5-52. What ECCM feature allows a radar to track a target that masks its return echo?

1. Iagc
2. Ftc
3. PAT
4. Stc

5-53. What are the two primary functions performed by a reliable fire control radar operator to eliminate confusion and surprise from radar countermeasures?

1. Identifying and reporting the jamming
2. Recognizing and identifying the jamming
3. Reporting the jamming and manual tracking
4. Manual tracking and recognizing the jamming

Learning Objective: Identify precautions to be taken when involved with radiation hazards and working aloft.

5-54. Personnel may develop a false sense of security concerning exposure to radiation because

1. rf hazards occur only at night
2. rf radiation is visible only at night
3. rf radiation does not always produce pain
4. only search radars are hazardous

5-55. Which of the following is NOT a radiation hazard?

1. Defective dummy loads
2. Open waveguides
3. Rotating search radars
4. Unavailability of warning signs

5-56. Which of the following conditions would be most likely to result in injury from x-rays?

1. Standing near unshielded high-voltage components
2. Working alone on low-voltage power supplies
3. Bypassing interlocks on shielded equipment
4. Working too close to a crt with a potential of 1500 volts

5-57. You are aloft. Which of the following items may be hazardous to you?

1. Static electricity
2. Rotating antennas
3. Stack gases
4. Each of the above

5-58. Whose permission must be obtained before going aloft?

1. The XO and the operations officer
2. The XO and the electronics officer
3. The electronics officer only
4. The OOD and the engineering officer

Learning Objective: Describe missile weapon system electrical power distribution and requirements.

5-59. Which of the following electrical characteristics apply to most naval a.c. power distribution systems?

1. 60 hz, 30, ungrounded
2. 60 hz, 10, grounded
3. 400 hz, 20, ungrounded
4. 400 hz, 10, ungrounded

5-60. Load centers are used by some ships to provide which of the following functions?

1. Emergency switchboard
2. Distribution panel
3. Remote switchboard
4. Impedance monitor

5-61. After normal power is lost, when will an alternate source be available?

1. Upon notifying the electricians
2. Upon notifying the OOD
3. After resetting the switchboard
4. Automatically

5-62. Bus transfer units enable a selection between which of the following?

1. Two inputs only
2. Two or more inputs
3. Two outputs only
4. Two or more outputs

5-63. The guided missile launching system is fed electrical power through which of the following units?

1. ABT only
2. ABT and power distribution panel
3. MBT and power distribution panel
4. MBT and load center

5-64. Which of the following voltages pass through the IC switchboard?

1. Relay supplies, synchro supplies and all 400 Hz power
2. Relay supplies, and all IC and fire control circuits
3. Relay supplies, synchro supplies, and all IC circuits
4. All 400 Hz power and all fire control circuits

5-65. Where does the 115V, 60 Hz power come from?

1. Turbines
2. Transformers
3. Generators
4. Rectifiers

5-66. Precision 400 Hz voltage is provided by which of the following sources?

1. Double-filter rectifier
2. Matched transformers
3. Voltage regulator
4. Motor generator

5-67. Your equipment is missing a certain voltage input. Which of the following actions should you take first?

1. Call an electrician's mate
2. Check the output of the switchboard
3. Energize the emergency generator
4. Check the ABT/MBT and power panel that feeds your equipment

Learning Objective: Name and compare the various sources of dry air for the weapon system.

5-68. What is the normal source of dry air for weapon system use?

1. Nitrogen bottles
2. A central system
3. The atmosphere
4. Local dehydrators

5-69. What is the major difference between the ship service and vital service lp air mains?

1. Priority
2. Pressure
3. Type of dessicant
4. Moisture content

5-70. What is the difference between the electronics branch requirements and those of the vital services main?

1. Priority
2. Pressure
3. Type of dessicant
4. Moisture content

5-71. Excessive moisture in certain electronic components can cause which of the following conditions?

1. Arcing and corrosion
2. Degraded performance
3. A need for overhaul
4. Each of the above

5-72. What is the air control panel designed to control?

1. Flow
2. Pressure
3. Purity
4. Dew point

5-73. The air control panel does NOT provide for monitoring of which of the following dry air properties?

1. Flow
2. Pressure
3. Purity
4. Dew point (humidity)

5-74. What air control panel component provides for control of outlet air pressure when normal pressure regulators malfunction?

1. Metering valve bypass
2. Secondary regulator
3. Intermediate regulator
4. Relief valve

5-75. Which of the following units may be available as an emergency back-up to the control dry air system?

1. Local dehydrator
2. Local compressor-dehydrator
3. Nitrogen tank
4. Each of the above

Assignment 6

Support Systems, Administration, and Maintenance

Textbook Assignment: FTM3, NAVEDTRA 10224; pages 6-7 through 8-3

Learning Objective: Identify the major units, requirements, and characteristics of the electronics liquid cooling system.

6-1. Which of the following characteristics of cooling water for electronic equipment must be carefully controlled?

1. Purity
2. Pressure
3. Quantity
4. All of the above

6-2. Which of the following is NOT a main component of the liquid cooling system?

1. Expansion tank
2. Freon tank
3. Circulating pump
4. Demineralizer

6-3. Which of the following water resources is/are used for primary cooling?

1. Seawater only
2. Chilled water only
3. Seawater and chilled water
4. Potable water and seawater

6-4. What determines the type of primary cooling system variation to be used?

1. Location of equipment
2. Amount of equipment
3. Temperature requirements
4. Safety requirements

IN ANSWERING QUESTION 6-5 REFER TO TEXTBOOK FIGURE 6-7 ON PAGE 6-9.

6-5. Which of the following units is used only in a primary cooling system?

1. Strainer
2. Expansion tank
3. Circulating pump
4. Demineralizer

6-6. Some cooling systems use which of the following units to help stabilize temperature sensitive components?

1. Expansion tank
2. Temperature interlock
3. Coolant heater
4. Water level stabilizer

6-7 When a two-way temperature-regulating valve is used, it controls the flow of which of the following coolants?

1. Primary
2. Secondary
3. Seawater only
4. Distilled water only

6-8. Some cooling water systems have installed demineralizers. They are designed to maintain which of the following water characteristics?

1. Clarity
2. Purity
3. Specific gravity
4. All of the above

6-9. A demineralizer is designed to remove which of the following substances from cooling water?

1. Dissolved metals
2. Chlorine
3. Waste
4. Oil

6-10. Where would a gravity tank be located in a liquid cooling system?

1. Above the highest point in the system
2. At the lowest point in the system
3. At the highest point in the system
4. Below the circulating pump

6-11. Which of the following devices are used to protect and/or monitor the liquid cooling system?

1. Switches and alarms
2. Remote indicators and gages
3. Interlocks and flow switches
4. All of the above

6-12. The desired purity level of the coolant in the secondary loop is determined by which of the following?

1. Piping material
2. Size of the cooling system
3. Requirements of the electronic equipment
4. All of the above

6-13. Which of the following actions can be taken to ensure the proper purity level of coolant water?

1. Separate water tests
2. Periodic tests of meters
3. Routine observation of installed meters
4. Each of the above

6-14. The purity cells in the demineralizer measure which of the following characteristics?

1. Acidity
2. Content
3. Resistivity
4. Specific gravity

6-15. Drinking water, even when it comes from the distilling plant, is unacceptable for cooling systems due to the presence of

1. salt
2. chlorine
3. flouride
4. bacteria

Learning Objective: Identify and describe fire control related administrative documents.

6-16. Fire control equipment operation and maintenance policies are partially based on data obtained from records and reports submitted to

1. CNO
2. naval engineers
3. NAVSEASYSCOM
4. the commanding officer

6-17. Which of the following documents contain fire control equipment design change instructions?

1. Change memos
2. ORDALTs
3. Design specifications
4. Equipment change guides

6-18. A correspondence loop is also called

1. booking
2. feedback
3. ordnance alteration
4. paperwork

6-19. Which of the following Naval System Commands issues technical publications which concern FTMs?

1. NAVSEASYSCOM only
2. NAVSHIPSYSCOM only
3. NAVSUPSYSCOM and NAVSHIPSYSCOM
4. NAVSUPSYSCOM and NAVSEASYSCOM

6-20. The leading petty officer in your division has advised you to consult NAVORD OP 3000 (Vol. 1), Weapons System Fundamentals. The abbreviation OP in the foregoing designation stands for

1. ordnance publication
2. ordnance pamphlet
3. operations publication
4. operational priority

6-21. Which of the following organizations may prepare OPs concerning ordnance equipment?

1. NAVSEA
2. Equipment manufacturer
3. Commercial publisher
4. Each of the above

6-22. Which of the following publications deals with the effective use of specific ordnance equipment?

1. Equipment OPs
2. General OPs
3. Ordnance instructions
4. Ordnance notices

6-23. Which of the following ordnance publications are designed to be a reference book for a subject matter area?

1. Notices
2. Instructions
3. General OPs
4. System OPs

6-24. Which of the following publications cover system support equipment maintenance?

1. Technical manuals
2. System OPs
3. Equipment ODs
4. Support OPs

6-25. Under a new system developed by the Navy, technical publications will have a standardized

1. numbering system
2. contents format
3. construction
4. number of volumes

6-26. Which of the following publications are included under the new numbering system known as TMINS?

1. All OPs
2. All TMs
3. Both 1 and 2 above
4. New or newly revised publications

6-27. Which of the following methods is proper to use in revising an OP?

1. Pen and ink correction
2. Page replacement
3. Section replacement
4. Each of the above

6-28. What type of change does NAVSEASYSCOM use to disseminate urgent information concerning conditions hazardous to the fleet?

1. CH
2. MC
3. ACN
4. FCH

6-29. What type of change provides formal replacement pages that cover configuration changes (ORDALTS and SHIPALTS)?

1. CH
2. MC
3. ACN
4. FCH

6-30. Which of the following characteristics is/are essential for making proper changes to technical publications?

1. Accuracy
2. Timeliness
3. Applicability
4. All of the above

6-31. Which of the following publications provides up-to-the-minute information on maintenance problems and procedures for missile fire control equipment?

1. OP 0
2. OD 9398
3. SMS technical bulletin
4. NAVPUBINST 5215.4B

6-32. Which of the following is NOT a use of SMS technical bulletins?

1. Provide troubleshooting techniques
2. Provide ORDALT instructions
3. Call attention to technical problems
4. Call attention to new test procedures

6-33. Which of the following documents are used by engineering experts to report problems?

1. CONARS
2. DCAP forms
3. OPNAV 4790/2Ks
4. Each of the above

6-34. Which of the following documents are issued to complete the DCAP information loop?

1. Periodical status reports
2. ORDALT instructions
3. Updated allowance parts lists
4. Procedural changes

IN ANSWERING QUESTIONS 6-35 THROUGH 6-37 SELECT FROM COLUMN B THE INFORMATION THAT IS FOUND IN THE PUBLICATION LISTED IN COLUMN A.

	A. PUBLICATION	B. INFORMATION
6-35.	NAVSHIPSYSCOM Technical Manual	1. Installation and maintenance information for naval electronic equipment
6-36.	NAVSHIPSYSCOM Electronic Installation and Maintenance Book	2. Problem data pertaining to system support equipment
6-37.	SMS DCAP status report	3. Data and instructions pertaining to classes of installed machinery and equipment
		4. Wiring diagrams of fire control equipment

6-38. Which of the following responsibilities are included in handling classified material?

1. Making changes
2. Proper receipt
3. Proper distribution
4. All of the above

6-39. The reference to use for questions of security in the Navy is

1. Basic Military Requirements
2. OPNAVINST 5510.1
3. Ship's Security Manual
4. NAVSEA Security Manual

Learning Objective: Recognize weapon system administrative forms/reports and identify their basic content.

6-40. Printed forms have an advantage over narrative reports because in printed form

1. the information does not need checking
2. reporting is quicker and simpler
3. the information is easier to file
4. both 2 and 3 above

6-41. What form provides data that serves as a basis for identifying and correcting surface missile system deficiencies?

1. 5510/1
2. 4855/2
3. 4855/2K
4. 4790/2

IN ANSWERING QUESTIONS 6-42 THROUGH 6-44 SELECT FROM COLUMN B THE CLASSIFICATION THAT APPLIES TO THE LOG ENTRY IN COLUMN A.

	A. LOG ENTRY	B. CLASSIFICATION
6-42.	Missile frequency	1. Unclassified
		2. Confidential
6-43.	Missile system test results	3. Secret
		4. Top Secret
6-44.	Missile firing results	

6-45. Under which of the following circumstances should an OPNAV 4790/2K be filled out?

1. Inability to complete a maintenance task
2. Completion of maintenance on a selected equipment
3. Deferral of work for outside assistance
4. Each of the above

6-46. You have corrected a unique problem in your equipment. Which of the following forms or reports should you use to report the problem and your corrective action?

1. OPNAV 4790/2K
2. CONAR
3. Both 1 and 2 above
4. 8810/3

6-47. In which of the following places should you document the completion of fire control ORDALT?

1. On the ORDALT plate
2. In the nonexpendable SMS Equipment Status Log
3. On a 3-M form
4. In all of the above places

6-48. Which of the following documents identifies ordnance hardware configuration?

1. SAIL
2. NAVSEA ORDALT 00
3. OPNAV 4790.4
4. All of the above

6-49. What organization is responsible for the procurement and distribution of SMS equipment ORDALTs?

1. NAVSEA
2. NSWSES
3. Department of the Navy
4. Department of Defense

6-50. Which of the following organizations assist(s) in determining equipment's ORDALT status and requirements?

1. NAVSEACENLANT
2. NAVSEACENPAC
3. Both 1 and 2 above
4. NSWSES

Learning Objective: Identify and describe aspects of the supply system pertinent to FTMs.

6-51. The FTM is responsible for which of the following supply duties?

1. Identifying needed parts
2. Submitting request forms
3. Reporting use of parts
4. Each of the above

6-52. Which of the following types of repair parts would most likely be stored in the work space?

1. Large expensive expendables
2. Large rarely used parts
3. Small frequently used parts
4. Small rarely used parts

6-53. Which of the following publications lists equipments, components and repair parts needed to operate and maintain the ship?

1. COSAL
2. Federal Supply Catalog
3. IPB
4. SPCC

6-54. Which of the following categories include(s) equipage items?

1. Portable
2. Very expensive
3. Subject to theft
4. All of the above

6-55. Which of the following documents is used to find allowed ordnance equipment repair parts?

1. COSAL Part 1
2. COSAL Part 2
3. COSAL Part 3
4. Federal Supply Catalog

6-56. Which of the following publications contain stock numbers for repair parts?

1. Technical manuals and NAVSEA OPs
2. Technical manuals and FSS
3. COSAL and Federal Supply Catalog
4. COSAL and NAVSEA OPs

6-57. Which of the following information is usually omitted from the manufacturer's nameplate?

1. Manufacturer's name
2. Model number
3. Federal stock number
4. Voltage

6-58. Which of the following ways should repairables be packaged for return to the supply department?

1. In an appropriately designed container
2. In a plastic bag stuffed with wadded paper
3. With all usable parts removed
4. With the defective component removed

6-59. When should "mandatory turn-in" items be returned to supply?

1. After cannibalizing necessary components
2. As soon as practicable
3. Before a new part is ordered
4. Immediately upon ordering a new part

Learning Objective: Specify the importance of equipment maintenance and the use of troubleshooting aids provided for equipment maintenance.

6-60. In which of the following publications can you find a special maintenance procedure for a computer?

1. The appropriate SMS guide
2. The appropriate OP
3. The Ordnance Log
4. The COSAL

6-61. How is the knowledge required to skillfully perform general maintenance normally acquired?

1. By OJT and attending "A" school
2. By attending "A" school and studying maintenance requirement cards
3. By OJT and studying rate training manuals
4. By studying the appropriate equipment OPs

6-62. Which of the following is a source of the specific safety precautions to observe when you perform maintenance procedures?

1. The MRC
2. The SMS guide
3. The OP
4. The Ordnance Log

6-63. What term is applied to the systematic accomplishment of items necessary to reduce or eliminate failures and prolong the useful life of equipment?

1. Technical maintenance
2. Preventive maintenance
3. Equipment preservation
4. Operational maintenance

6-64. Which of the following actions comes under the heading of corrective maintenance?

1. Retuning a radar receiver after a tube casualty
2. Inspecting a radio transmitter for a loose connection during transmission
3. Oiling the gimbal mechanism of a stable vertical during operation
4. Removing dust from the brushes of an operating generator

6-65. Which of the following is a characteristic of system level testing?

1. Experienced technicians carry the workload
2. Tasks are performed only when a system casualty occurs
3. Equipments are tested in relation to others in the system
4. Individual equipment casualties cannot be detected

6-66. What is the standard used for scheduling in the Planned Maintenance System?

1. Maximum testing as directed by the ship's captain
2. Testing only prior to system operation
3. Testing only subsequent to system operation
4. Minimum testing that ensures material readiness

6-67. Which of the following individuals is responsible for scheduling shipboard preventive maintenance procedures?

1. The CNO
2. The ship's captain
3. The ship's weapons officer
4. The senior FTM

6-68. Which of the following documents contains equipment test procedures?

1. Equipment OP supplements
2. Equipment servicing manuals
3. PMS manuals
4. MRCs

6-69. Equipment troubleshooting aids do NOT include a

1. fault logic diagram
2. troubleshooting index
3. maintenance turn-on procedure
4. signal flow diagram

Assignment 7

Trouble Isolation and General Maintenance

Textbook Assignment : FTM3, NAVEDTRA 10224; pages 8-3 through 8-25

Learning Objective: Specify the importance of equipment maintenance and the use of troubleshooting aids provided for equipment maintenance.

7-1. When troubleshooting an equipment, you reach the equipment's output without isolating the malfunction. To which of the following documents should you refer to review the applicable signal flow diagram associated with the equipment under test?

1. Relay ladder diagram
2. Power distribution diagram
3. Troubleshooting index
4. Schematic diagram

7-2. The troubleshooting aid in the equipment OP that indicates test points, test parameters, and adjustments is known as a

1. maintenance turn-on procedure
2. signal flow diagram
3. troubleshooting index
4. adjustment index

7-3. You should always exercise caution when using the signal flow diagrams because these diagrams present only

1. static operating conditions
2. troubleshooting test condition parameters
3. normal operating parameters
4. parameters without scope displays

7-4. What is the normal method of tracing main signal flow across a signal flow diagram?

1. From top to bottom
2. From left to right
3. From bottom to top
4. From right to left

7-5. Why do some signal flow diagrams reference other signal flow diagrams?

1. The referenced signal flow diagrams show power distribution
2. The signal flow diagrams are too small to show all details
3. The referenced signal flow diagrams are common to more than one output function
4. The signal flow diagrams have changed because of modifications

7-6. Troubleshooting a suspected open circuit can best be accomplished by using the

1. signal flow diagrams
2. maintenance turn-on procedures
3. troubleshooting index
4. relay ladder

7-7. What basic troubleshooting diagram is used for equipment switching problems?

1. Power distribution
2. Schematic
3. Relay ladder
4. Signal flow

7-8. Which of the following components is/are NOT illustrated on power distribution diagrams?

1. Cable connections
2. Chassis inputs
3. Terminal boards
4. Unit circuitry

7-9. To increase your knowledge of the detailed circuitry in a weapons system's equipment, what should you study in your equipment OP?

1. Relay ladder diagrams
2. Isolation procedures
3. Schematic diagrams
4. Maintenance turn-on procedures

7-10. Which of the following is a great aid to a technician in simplifying complex trouble-shooting jobs?

1. Specified test equipment
2. General-purpose test equipment
3. The replace-and-try system of equipment elimination
4. Proper troubleshooting procedure and common sense

7-11. Which of the following conditions could cause the input power to a piece of equipment to be missing?

1. A loose cable
2. An open circuit breaker
3. A switch in the wrong position
4. Each of the above

7-12. Assume that in troubleshooting a system on which there is a reported failure, you determine that the circuit breaker which protects the equipment in question is tripped, and after checking thoroughly, you find NO apparent short. What should be your next action?

1. Reset the circuit breaker and apply power
2. Remove the system components for bench checking
3. Replace the circuit breaker
4. Unplug all system components, reset the circuit breaker, and plug in the system components one at a time

7-13. Which of the following tests will normally locate a faulty plug connection?

1. Stress test
2. Continuity test
3. System test
4. Megger test

7-14. Besides repairing or replacing a faulty component, which of the following actions is/are also recommended?

1. Find the cause of damage
2. Perform operational checks
3. Make needed adjustments
4. All of the above

7-15. The probes of some test equipment have a capacitor in series with the input for the purpose of

1. creating an infinite a.c. impedance between the probes and the circuit under test
2. minimizing signal loss due to mismatched impedances between the probes and the circuit under test
3. preventing d.c. from the circuit under test from being applied to the test equipment
4. preventing a.c. from test equipment from being applied to the circuit under test

7-16. Test probes should NOT be shifted from one type of test equipment to another because

1. the probe resistance may be wrong for the equipment under test
2. the current carrying capability of the probe may be too small for the equipment under test
3. voltage ratings of the probes may be exceeded
4. unmatched connector shielding may result in erroneous readings

7-17. Solid state assemblies can withstand considerable abuse in usage; however, it is necessary to take great care when performing maintenance on these parts for which of the following reasons?

1. Components used are susceptible to damage from heat during the soldering process
2. Components such as transistors are highly susceptible to damage by stray voltages from test equipment
3. Parts are smaller and closer together, making them more susceptible to injury when adjacent parts are being removed
4. All of the above

7-18. Which of the following actions would likely result in a solid state component being damaged?

1. Applying a minimum of heat while soldering
2. Grounding a meter to the module chassis
3. Removing a module with power applied
4. Discharging a voltmeter before testing a PC

7-19. When repairing a broken foil on a PC board, which of the following actions would result in a bad repair?

1. Use of a pencil iron
2. Replacement with a piece of bare wire
3. Solder flow to other printed areas
4. Lifting of foil from the board

7-20. A repair job is considered to be complete after the

1. faulty component has been replaced
2. shields and dust covers have been installed
3. operational test has been performed
4. operational check under normal operating conditions has been completed

7-21. One purpose of the maintenance requirement cards is to provide the information necessary to perform which of the following actions?

1. isolate malfunctions
2. correct malfunctions
3. schedule maintenance
4. illustrate components

7-22. Adjustment procedures are performed at which of the following times?

1. At least annually
2. After a part replacement
3. Whenever scheduled
4. All of the above

7-23. Alignment/adjustment MRCs are NOT referenced from which of the following documents?

1. Schematic diagrams
2. Signal flow diagrams
3. Test MRCs
4. Repair MRCs

Learning Objective: Relate various aspects of basic preventive maintenance tasks.

7-24. Grease on the chassis of a fire control system can be removed by wiping with a

1. clean, lint-free cloth moistened in solvent
2. soapy, clean, lint-free cloth
3. clean, dry, lint-free cloth
4. tissue paper

7-25. The procedure for lubricating antenna rotating joints is outlined in the

1. pertinent MIL SPECs
2. United States Navy Safety Precautions
3. equipment MRCs
4. pertinent Maintenance Instructions Manual

7-26. Cross-reference guides are available for substitution of which of the following?

1. Test procedures
2. Alignment procedures
3. Cleaning cloths
4. Lubricants

7-27. Errors can be caused in some fire control equipment by which of the following?

1. Dust and dirt
2. Wear
3. Moisture
4. Each of the above

7-28. You remove a defective SMS mechanical component to the ship's repair shop and disassemble it. How are the disassembled parts stowed pending repair?

1. In rust-inhibiting oil baths
2. On open shelves
3. In ventilated bins
4. Under lint-free dust covers

7-29. When using solvent, you should observe which of the following practices to prevent excessive wear of a mechanical component?

1. Avoid spraying it on
2. Wrap the component in plastic
3. Spray from a long distance
4. Spray it in short bursts only

7-30. Grease is used sparingly on fire control equipment because heavy application of grease tends to

1. prevent the dissipation of heat
2. clog the mechanism
3. speed up corrosion
4. absorb dirt particles

7-31. A routine inspection of a fire control radar reveals a blackened area around a resistor. This condition is an indication of probable

1. condensation
2. excessive vibration
3. overheating
4. overinsulation

Learning Objective: Describe general maintenance related to rotating machinery.

7-32. Which of the following statements concerning brushes is true?

1. Used brushes should NOT be reinserted after removal
2. Brushes should be reinserted in their original location and position
3. For maximum wear, brush locations should be rotated
4. For maximum use, brush positions should be reversed

7-33. What is the ideal appearance of the surface of a slipring?

1. Bright and smooth
2. Rough matte finish
3. Smooth matte finish
4. Slightly grooved

7-34. What is the normal appearance of a commutator?

1. Shiny and black
2. Dull and black
3. Shiny and brown
4. Dull and brown

7-35. Which of the following defects in a commutator would an FTM normally repair aboard ship?

1. Faulty brush contact
2. Open coil
3. Shorted coil
4. High mica

7-36. The condition called high mica is caused by

1. arcing from the brushes
2. arcing between segments
3. excessive brush wear
4. excessive copper wear

7-37. Under which of the following conditions should brushes be replaced?

1. Oil soaked
2. Chipped
3. Excessive wear
4. Each of the above

7-38. When new brushes are sanded in prior to use, a good way to secure the sandpaper to the commutator is with

1. a small dab of glue
2. friction tape
3. rubber bands
4. transparent adhesive tape

7-39. When you clean dirt or grease from glass optics, the lens tissue should be dampened with

1. alcohol
2. an alkaline solution
3. plain water
4. soapy water

Learning Objective: Specify the environmental factors affecting fire control equipment and the correct methods for minimizing their effects.

7-40. What is the environmental condition that causes metal components to become brittle?

1. Extremely low temperatures
2. Extremely high temperatures
3. Low humidity
4. High atmospheric pressure

QUESTIONS 7-41 THROUGH 7-43 ARE TO BE JUDGED TRUE OR FALSE.

7-41. The effectiveness of heating and cooling equipment is NOT affected by the presence of dirt and dust on its outside surface.

7-42. Short circuiting between points of high potential may result from the operation of electronic equipment in a high-humidity environment.

7-43. Troubles with pressurized systems are usually caused by severe vibration.

7-44. Undesired environmental effects of temperature, humidity, arcover, and abrasive conditions are minimized by the use of

1. electric heaters
2. hot air blowers
3. air conditioning
4. silica gel crystals

7-45. Corrosion has an adverse effect on equipment at which of the following times?

1. Only when the equipment is energized
2. Only when the equipment is deenergized
3. Whenever preventive maintenance is NOT done
4. Twenty-four hours a day

7-46. The preferred way to remove moisture from a connection box is with a

1. clean rag
2. lint-free cloth
3. hot-air blower
4. vacuum cleaner

7-47. What is the function of the silica gel crystals in the desiccant unit of an SMS component?

1. To moisten the air inside the unit
2. To dry the air inside the unit
3. To filter the incoming air
4. To reduce the interior heat

7-48. Before reenergizing an equipment where water has been used to remove salt, which of the following precautions should be observed?

1. Perform a salinity test
2. Go over the surface with a solvent
3. Install a bag of silica-gel crystals
4. Ensure that the water is completely evaporated

Learning Objective: State the causes of accidents and measures which should be taken in case of electrical shock.

7-49. The tendency to be overeager on the job is generally associated with

1. carelessness
2. fatigue
3. inexperience
4. overconfidence

7-50. The best way to avoid the effects of fatigue while working is to

1. prepare physically for the task
2. take many short rests
3. share the work with someone
4. relax while you work

7-51. Assume that the palm of your hand contacts a conductor, and 12 milliamperes of current flow through your body. You will probably suffer which of the following effects?

1. Ventricular fibrillation
2. Severe burns and unconsciousness
3. A slight tingling sensation
4. Contraction of your hand muscles and gripping of the conductor

7-52. What is the minimum amount of electrical current that can cause a fatal shock?

1. 1 milliampere
2. 10 milliamperes
3. 100 milliamperes
4. 1 ampere

QUESTION 7-53 IS TO BE JUDGED TRUE OR FALSE.

7-53. Low voltage electrical equipment can be as dangerous as high voltage equipment because under some conditions a relatively low voltage can create lethal current flow through the body.

7-54. Which of the following is the first step in rescuing a man who is in contact with an electric circuit and has been knocked unconscious?

1. Deenergize the circuit
2. Use a rope or wooden stick to separate the man from the circuit without touching him
3. 1 and 2 above are both correct, depending on the circumstances
4. Call the duty electrician

7-55. What should you do if a person is unconscious and has stopped breathing as a result of electrical shock?

1. Apply artificial respiration immediately
2. Ascertain the amount of the current that passed through the body to proceed with the proper treatment
3. Wrap the person in a blanket and get him to sick bay for treatment
4. Determine if his heart has stopped beating and, if not, apply artificial respiration

7-56. The proper treatment for a person who has received a severe electric shock but is still breathing is to

1. give him an opiate to relieve his anxiety
2. keep him walking or moving around so that he will not lose consciousness
3. apply artificial respiration to assist him in breathing
4. keep him lying down

7-57. Under which of the following conditions should you attempt CPR?

1. Whenever a medical officer is not available
2. If you have the proper training
3. After giving the victim a few minutes to start breathing on his own
4. Each of the above

Learninging Objective: Describe general safety precautions related to maintenance.

7-58. Which of the following precautions should be observed before using an electric drill?

1. Inspect the drill for proper operation
2. Check your safety equipment
3. Ground the drill with the lead on the plug
4. All of the above

7-59. While working on or very near machinery and rotating electrical equipment, it is common sense to remove ties and other loose clothing and to button shirt sleeves to prevent

1. arcing from clothing to equipment as a result of static charge
2. entanglement in moving parts
3. excessive perspiring
4. discomfort and fatigue

7-60. Which of the following is NOT a safety precaution that maintenance personnel should observe when working with energized circuits?

1. Working with one hand only as much as possible
2. Working only with metal handtools
3. Wearing rubber gloves
4. Standing on an insulated mat

7-61. Before making electrical repairs on the fire control system aboard your ship, you disconnect the system from the main power source. In the interest of safety, what additional step should you take before you start on the repair job?

1. Posting a man on watch at the place of disconnect of the power supply
2. Posting an out-of-order sign in a conspicuous place in the compartment where you are working
3. Tagging the power supply switch open
4. Disconnecting all main power supply leads

7-62. The recommended way to see if a 110-volt source is deenergized is to touch the circuit with your

1. finger
2. voltmeter
3. long-nose pliers
4. pencil

7-63. To ensure that a capacitor is completely discharged, you should

1. disconnect the circuit
2. short circuit the terminals
3. take a resistance reading
4. lightly tap the leads with your fingers

7-64. When using a safety shorting probe, whic of the following precautions should you observe?

1. Scrape the paint from the metal ground
2. Hold the shorting probe rod with insulating gloves
3. Connect the test clip to the capacitor first
4. All of the above

7-65. Most radioactive radiation hazards an FT will encounter will be occasioned by

1. monitoring radioactive storage spaces
2. carrying radioactive material on his person
3. breakage of components containing radioactive material
4. wearing clothing formerly worn by decontamination personnel

7-66. Which of the following precautions is NOT among the precautions for working with crts?

1. Do not scratch the surface
2. Discharge the anode before removal
3. Handle the crt with gloves
4. Use the hands to grab the crt by the neck

7-67. Solvents primarily present a health hazard in which of the following ways?

1. Acid burns to the skin
2. Blurred vision
3. Damage to lungs
4. Sterility

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7-68. Specific instructions concerning the handling of aerosol dispensers are found in/on

1. chapter 9670, NAVSHIPS Technical Manual
2. NAVMED P-5055
3. the label of the dispenser
4. the OP or TM

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PRINT OR TYPE

NRCC Fire Control Technician M 3
NAVEDTRA 10224

NAME ________________________________ ADDRESS ________________________________
Last First Middle Street/Ship/Unit/Division, etc.

____
City or FPO State Zip

RANK/RATE ________ SOC. SEC. NO. ________________ DESIGNATOR ________ ASSIGNMENT NO. ________

☐ USN ☐ USNR ☐ ACTIVE ☐ INACTIVE OTHER (Specify) ________________ DATE MAILED ________

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PRINT OR TYPE

NRCC Fire Control Technician M 3
NAVEDTRA 10224

NAME ______________________ Last First Middle **ADDRESS** ______________________ Street/Ship/Unit/Division, etc.

______________________ City or FPO State Zip

RANK/RATE ________ **SOC. SEC. NO.** ______________ **DESIGNATOR** ________ **ASSIGNMENT NO.** ________

☐ **USN** ☐ **USNR** ☐ **ACTIVE** ☐ **INACTIVE** **OTHER (Specify)** ______________ **DATE MAILED** ________

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PRINT OR TYPE

NRCC Fire Control Technician M 3
NAVEDTRA 10224

NAME ______________________________ ADDRESS ______________________________
Last First Middle Street/Ship/Unit/Division, etc.

____
City or FPO State Zip

RANK/RATE ________ SOC. SEC. NO. ____________________ DESIGNATOR ________ ASSIGNMENT NO. ________

☐ USN ☐ USNR ☐ ACTIVE ☐ INACTIVE OTHER (Specify) ________________ DATE MAILED ________

SCORE

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PRINT OR TYPE

NRCC Fire Control Technician M 3
NAVEDTRA 10224

NAME ______________________________ **ADDRESS** ______________________________
Last First Middle Street/Ship/Unit/Division, etc.

____
City or FPO State Zip

RANK/RATE ________ **SOC. SEC. NO.** ______________ **DESIGNATOR** ________ **ASSIGNMENT NO.** ________

☐ USN ☐ USNR ☐ ACTIVE ☐ INACTIVE OTHER (Specify) ______________ DATE MAILED ________

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PRINT OR TYPE

NRCC Fire Control Technician M 3
NAVEDTRA 10224

NAME ______________________ ADDRESS ______________________
Last First Middle Street/Ship/Unit/Division, etc.

____
City or FPO State Zip

RANK/RATE ________ SOC. SEC. NO. ______________ DESIGNATOR ________ ASSIGNMENT NO. ________

☐ USN ☐ USNR ☐ ACTIVE ☐ INACTIVE OTHER (Specify) ______________ DATE MAILED ________

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3	☐	☐	☐	☐	_____	28	☐	☐	☐	☐	_____	53	☐	☐	☐	☐	_____
4	☐	☐	☐	☐	_____	29	☐	☐	☐	☐	_____	54	☐	☐	☐	☐	_____
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